ELECTROMECHANICAL

components & systems | DESIGN

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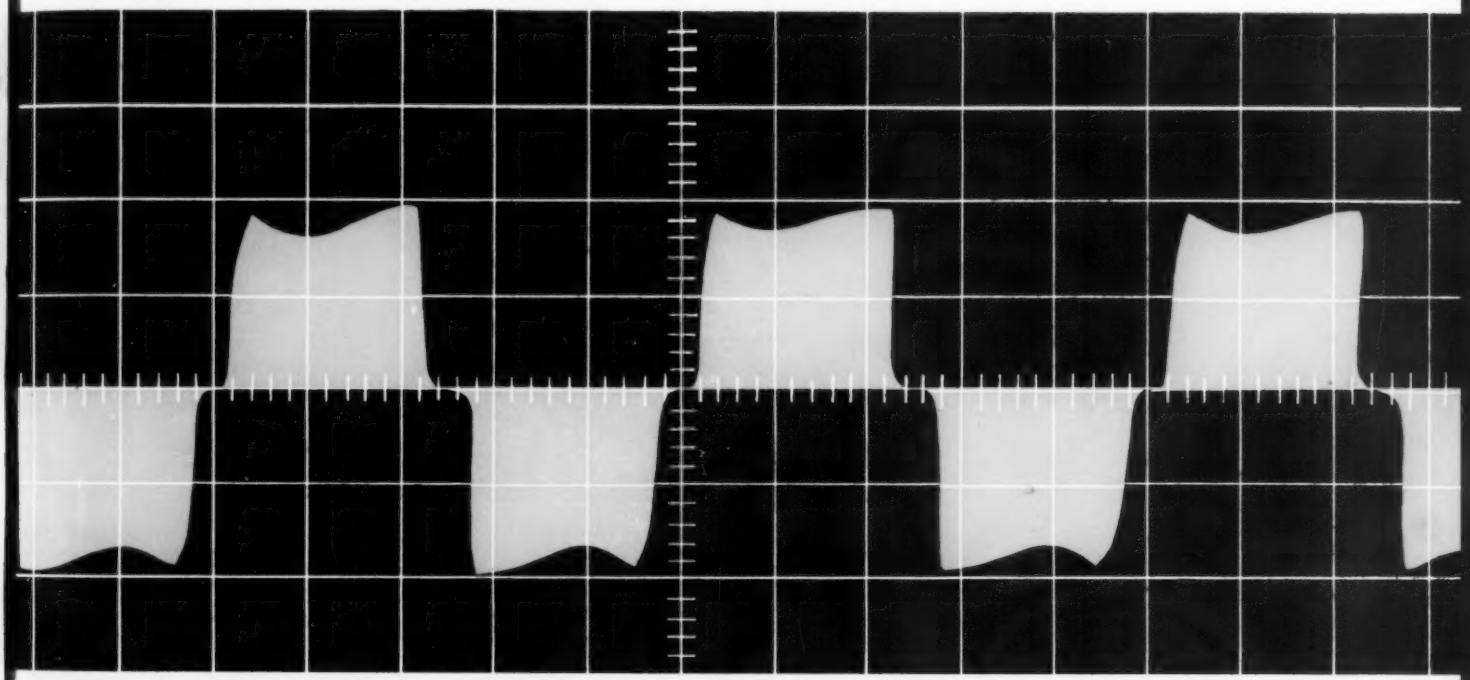
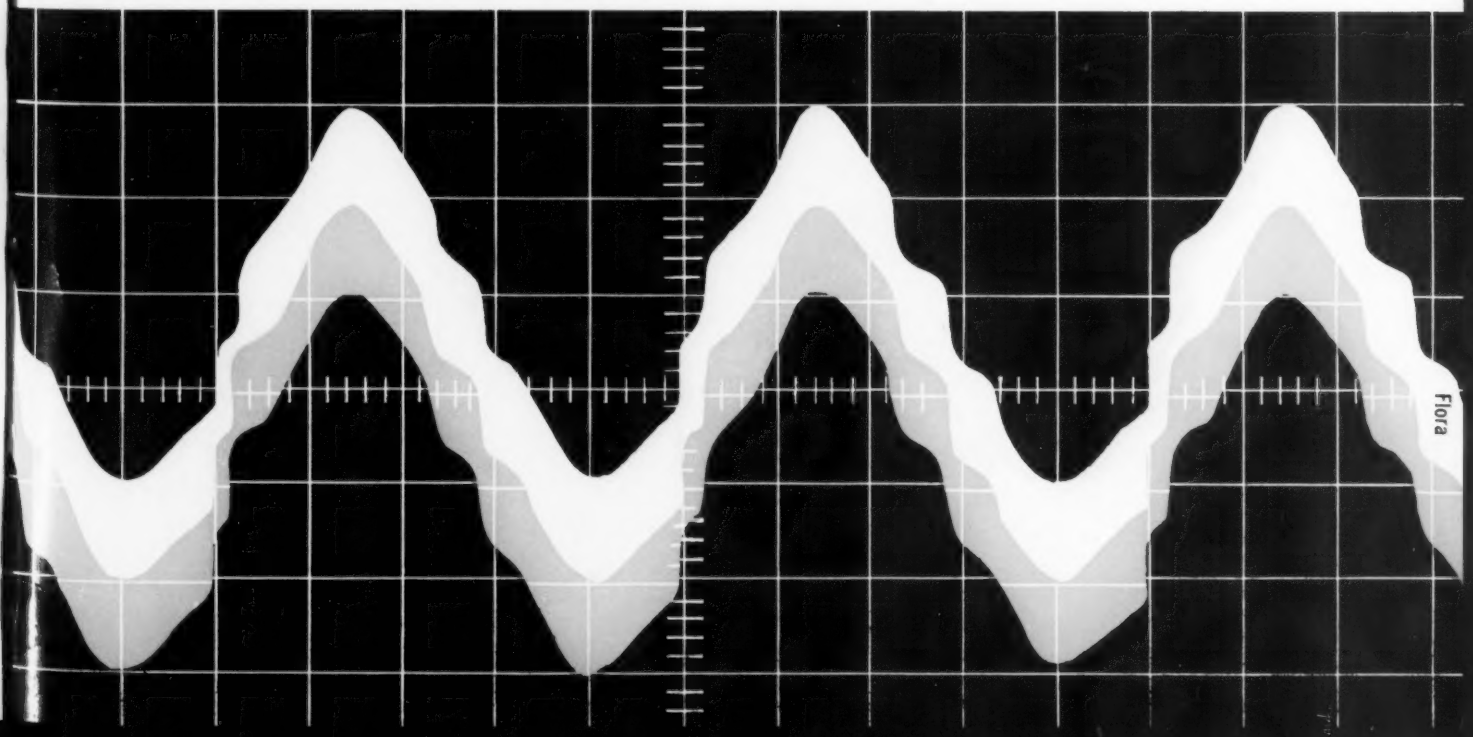
FILTERS FOR SERVO MODULATORS & DEMODULATORS



COMPONENTS DIGEST 20 part 2 · TIMING MOTORS



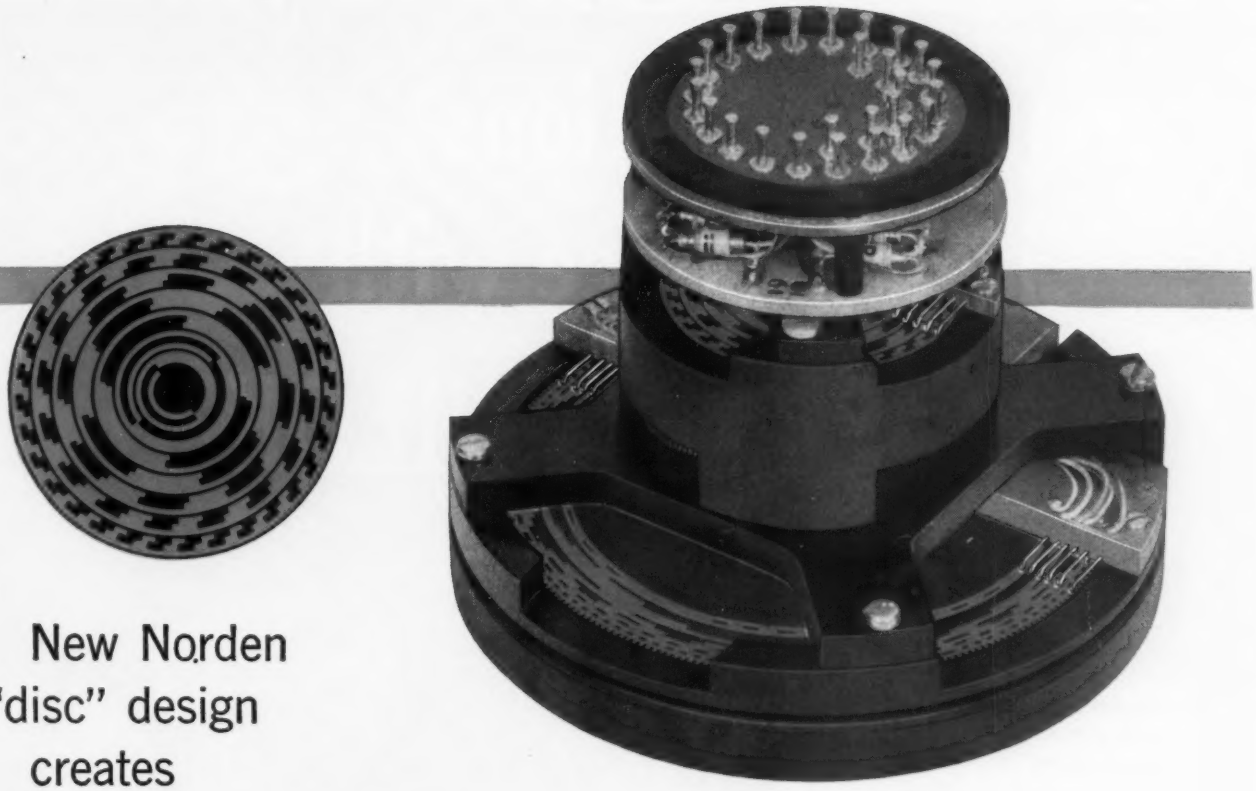
Flora

LIBRASCOPE COMPUTER FACILITIES

Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and production facilities. For your computer requirements, call on the company whose breadth of diversification in computer technology is unsurpassed. ■ Librascope Division, General Precision, Inc., 808 Western Avenue, Glendale, Calif. For career opportunities write to John Schmidt, Engineering Employment. ■

computers that pace man's expanding mind

CIRCLE NO. 1 ON INQUIRY CARD



New Norden "disc" design creates

High count, multiple turn Gray encoders ...without indexing mechanisms

Norden engineers have succeeded in incorporating double brush logic in a Gray encoder, model ADC-16-GRAY, achieving multiple turn capabilities and high resolution per turn . . . without the need for between-stage indexing mechanisms.

Norden ADC-GRAY code units:

- meet or exceed military specifications.
- assure freedom from error due to positional ambiguities.
- are the smallest multi-turn Gray encoders available, and store nearly twice as much in a given diameter as units using a pure binary code.
- eliminate ambiguity situations caused by cross-coupling, simplifying telemetering problems such as may arise in space satellites.

Norden offers several models in Gray-code encoders with a total count range of 2^8 to 2^{16}. Review your requirements and send for detailed specifications and drawings or call TEmple 8-4471.

TYPICAL MODELS	TOTAL COUNT	REVOLUTIONS FOR FULL COUNT	DIAMETER
ADC-16-GRAY	65536	64	3.25
ADC-ST10-GRAY	1024	1	3.25
ADC-ST9-GRAY	512	1	2.25
ADC-ST8-GRAY	256	1	1.75

NORDEN

UNITED AIRCRAFT CORPORATION
NORDEN DIVISION
NORWALK, CONNECTICUT

CIRCLE NO. 2 ON INQUIRY CARD

more connections in less space with new MINILOK®!

CRIMP-TYPE CONNECTORS FOR MINIATURIZED ELECTRONIC PACKAGING

Space-saving compactness... occupies only ⅛ the volume formerly required for modular terminal block connectors...permits 100 connections in only 2½ inches!

Modular versatility: top and side modules quickly interlocked on the same track...plastic track easily cut to desired length...varied bussing arrangements available...snap-in HYTIP® contacts simplify wiring assembly and circuit changes.

Proven performance: now in volume production...embody field proven features...track, modules and end clamps molded of tough plastic ... improve dielectric characteristics... proven high-speed HYTIP contact installation tooling cuts installed costs and insures maximum reliability.

S-n-a-a-a-a-a-p-p modules together!

For complete dimensional and performance data on MINILOK and other Burndy connectors contact

BURNDY

61-8

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CIRCLE NO. 3 ON INQUIRY CARD

ELECTROMECHANICAL
components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

MAY 1961 • VOL. 5 NO. 5

Contents

Components Design

14 FILTERS FOR SERVO MODULATORS AND DEMODULATORS
Notch filters reject unwanted frequencies without influencing servo information

24 VARIABLE SPEED DRIVE
Overload clutch, speed variator or torque multiplier for servo applications

Systems Design

28 ANTENNA MOUNT
Scimitar yoke type pedestal designed for end fire array

32 TEMPERATURE CONTROL
Controlled water supply heats or cools equipment to maintain constant temperature

Techniques

36 MODULAR PACKAGING
Universal incremental modules combine high structural strength with good economic maintainability

42 ARC IMAGING FURNACE
Contamination of specimen eliminated in new design

43 SIMPLE STRESS AND STRAIN
"Built-in" computer eliminates tedious calculations

Testing

44 MECHANICAL IMPEDANCE TESTING
Impedance head measures forces and accelerations at the same point

48 TRANSDUCER TESTER
Accurate thyratron circuit indicates test limits of voltage, resistance, shaft angle

Materials

52 FERRITE MATERIAL AND COMPONENTS
Magnetic-gyro characteristics of free electrons in ferrites provide unique properties

Design Time Saver

56 GRAPHICAL CALCULATIONS OF SYSTEMS NOISE FIGURES

Components Digest

59 TIMERS – COMPONENTS DIGEST 20, Part II, ELECTRIC TIMING MOTORS
Basic types, performance characteristics, governed dc motors, selection factors, application factors, commercial units

Departments

74 NEW COMPONENTS FOR ELECTROMECHANICAL SYSTEMS

77 CONTRACTS

78 NEW CATALOGS FOR YOUR LITERATURE FILE

79 INDEX TO ELECTROMECHANICAL DESIGN, 1957-1960

96 INDEX TO ADVERTISERS

98 PRODUCT INDEX

BPA Circulation for May over 29,000

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PRECISION MINIATURE A.C. & D.C. MOTORS. ACTUATORS, TIMERS. STEPPERS. BLOWERS. FANS. MOTORIZED DEVICES

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CIRCLE NO. 4 ON INQUIRY CARD

ELECTROMECHANICAL
components & systems **DESIGN**

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USE
MOTOR
LOAD

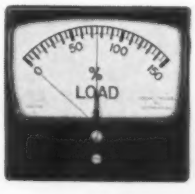
TO CONTROL
MACHINE OPERATIONS

Using motor load as the measured variable, API's Load Sentry is probably the most versatile—and perhaps the simplest—discrete machine control you're likely to find around. You can use it to switch from one feed rate to another, to measure actual accumulated work time or work count, to protect against mechanical or electrical overload from such causes as faulty work positioning, excessive torque, etc. All these conditions—and many more—are accurately reflected in motor-load current, a convenient means of control actuation.

Fast-acting Load Sentry will respond in less than 0.2 seconds to motor-load variations as little as 5% (in some cases 3%) of whatever norm you select. A simple index-pointer setting establishes the motor-load limit.

Built around the API contact meter-relay, Load Sentry is available as a simple contacting meter or a complete control package, ready to install. It has the inherent reliability of the locking-coil meter-relay: you can expect at least ten million operations without failure.

Load Sentry can be supplied to measure either amps or watts. It can be damped to limit response to steady overloads of up to three seconds' duration, and can include provision for start-up time delay. Bulletin 106-C will give you more detailed information.



api ASSEMBLY PRODUCTS, INC.
CHESTERLAND 79, OHIO

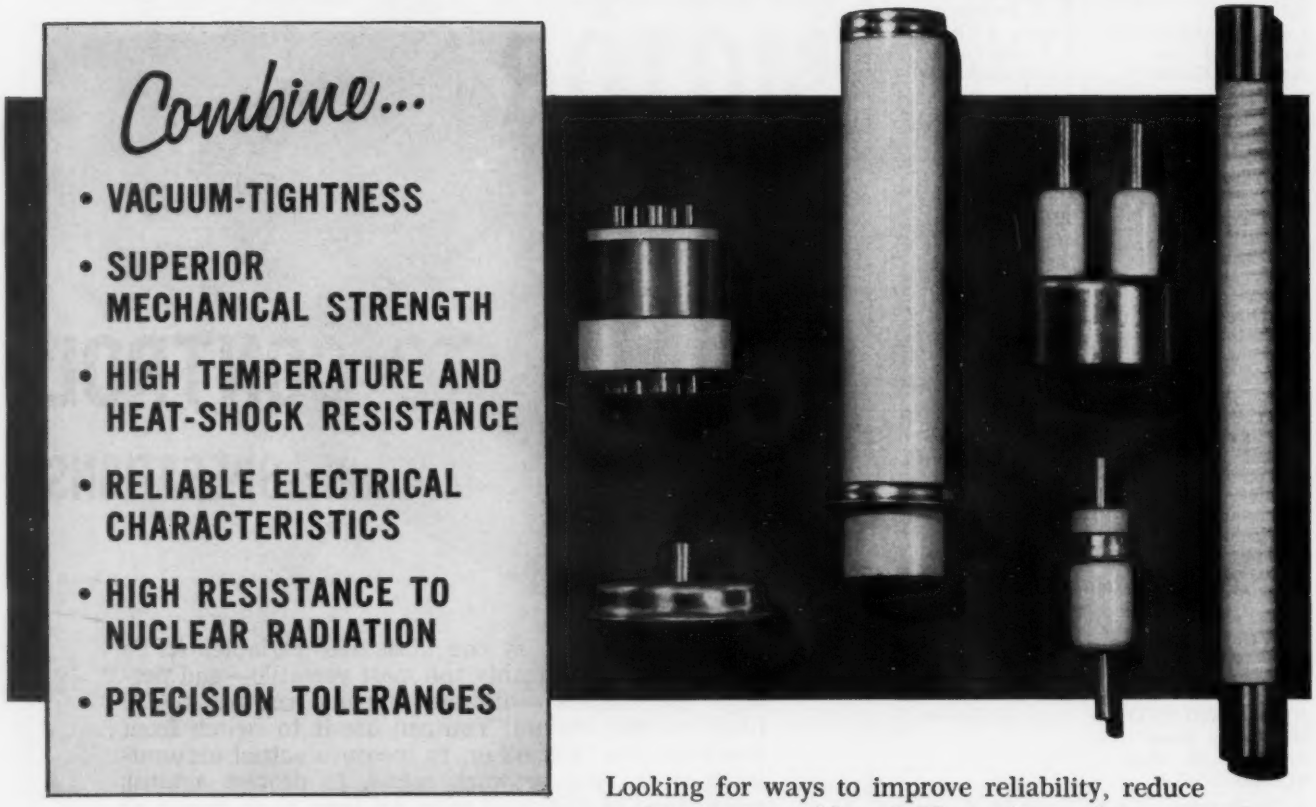
SA 2304

CIRCLE NO. 5 ON INQUIRY CARD

ALITE® HIGH-ALUMINA HERMETIC SEALS AND BUSHINGS

Combine...

- VACUUM-TIGHTNESS
- SUPERIOR MECHANICAL STRENGTH
- HIGH TEMPERATURE AND HEAT-SHOCK RESISTANCE
- RELIABLE ELECTRICAL CHARACTERISTICS
- HIGH RESISTANCE TO NUCLEAR RADIATION
- PRECISION TOLERANCES



Looking for ways to improve reliability, reduce maintenance problems? The unique advantages of Alite high-alumina ceramic-to-metal seals may be just what you need!

With maximum working temperatures in the range 1300°-1600°C., Alite can be metallized and brazed to metal parts to form rugged, vacuum-tight seals which, in turn, can be welded into final assemblies.

From design to finished part, every manufacturing step — including formulating, firing, metallizing and testing — is handled within our own plant and carefully supervised to assure strict adherence to specifications, utmost uniformity and reliability.

Over 100 standard sizes of Alite bushings in a range of types are available to simplify design problems and speed delivery. However, when special units are called for to meet unusual requirements, a team of Alite engineers stands ready to help you take advantage of Alite's superior properties.

Write for FREE Helpful Bulletins

Bulletin A-7R provides detailed description and specifications of Alite. Bulletin A-40 describes Alite facilities and complete line of standard bushings.

410-G

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U. S. STONEWARE

BOX 119 ORRVILLE, OHIO

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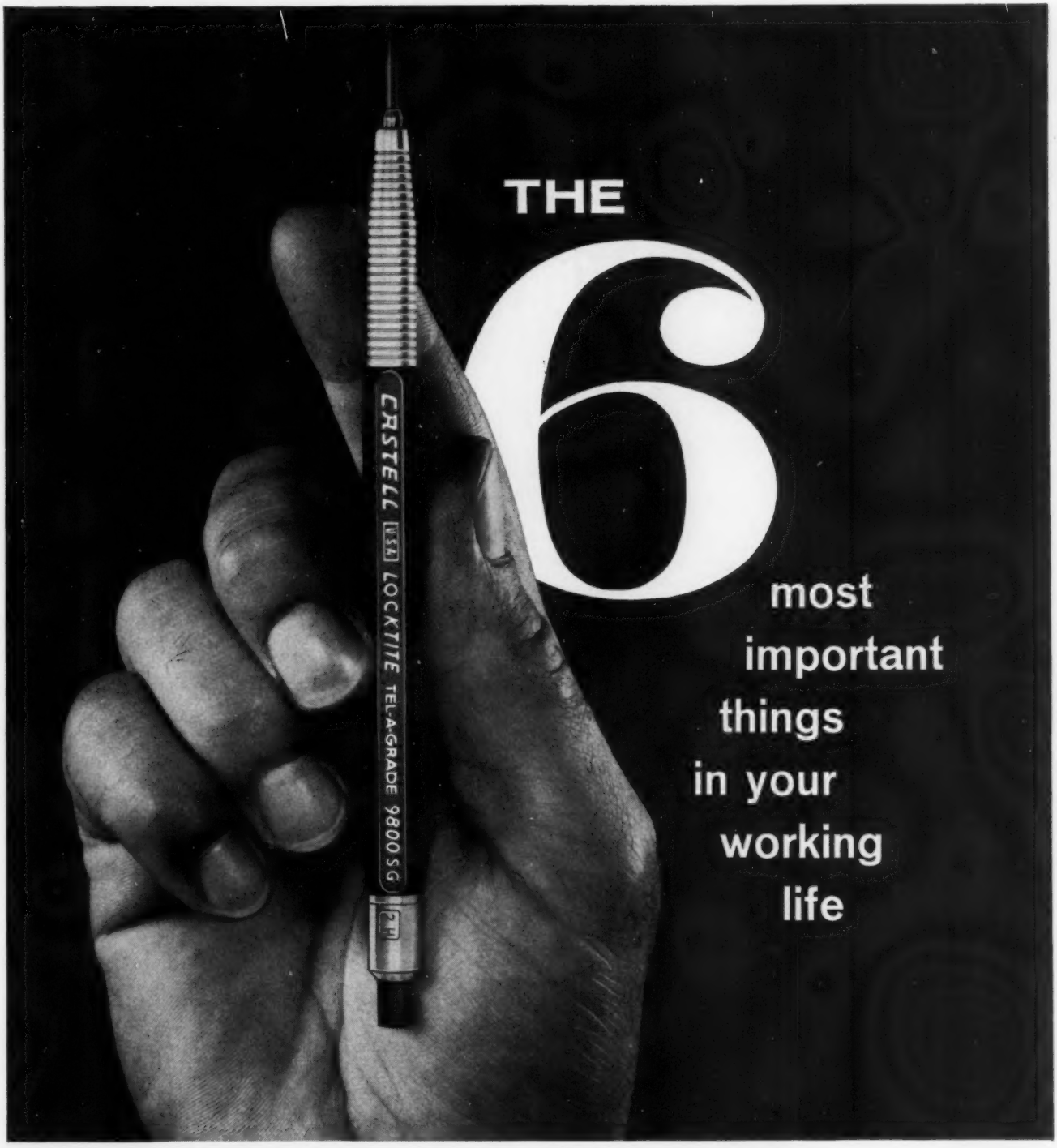

The 6 most important things in your working life are your five skilled fingers and your A.W.FABER #9800 SG LOCKTITE Tel-A-Grade Lead Holder.

LOCKTITE becomes a part of your creative process. The no-slip functional grip gives you smooth traction and practically banishes finger fatigue. Gun-rifled clutch holds the lead like the jaws of a bull dog. Unique indicator reveals the degree in use at a glance. Carries ironclad 2-year guarantee. A.W.FABER will replace the entire holder at no charge if any part wears out in normal usage. Yes, you can buy cheaper lead holders, but can you afford to let pennies stand between you and your perfect working tools? Buy quality —buy LOCKTITE, call your dealer today.

Castell Drawing Leads #9030, *are of the identical quality and grading as world-famous Castell wood pencil ■ Usable in all standard holders, but a perfect mate for Locktite ■ Draws perfectly on all surfaces, including Cronar and Mylar base films ■ Available in all degrees from 7B to 10H, and in a kaleidoscope of colors ■*

FABER-CASTELL

A.W.FABER-CASTELL
Pencil Co., Inc., Newark 3, N. J.

Our Bicentennial year—1761-1961
200 years of uninterrupted
manufacturing experience.

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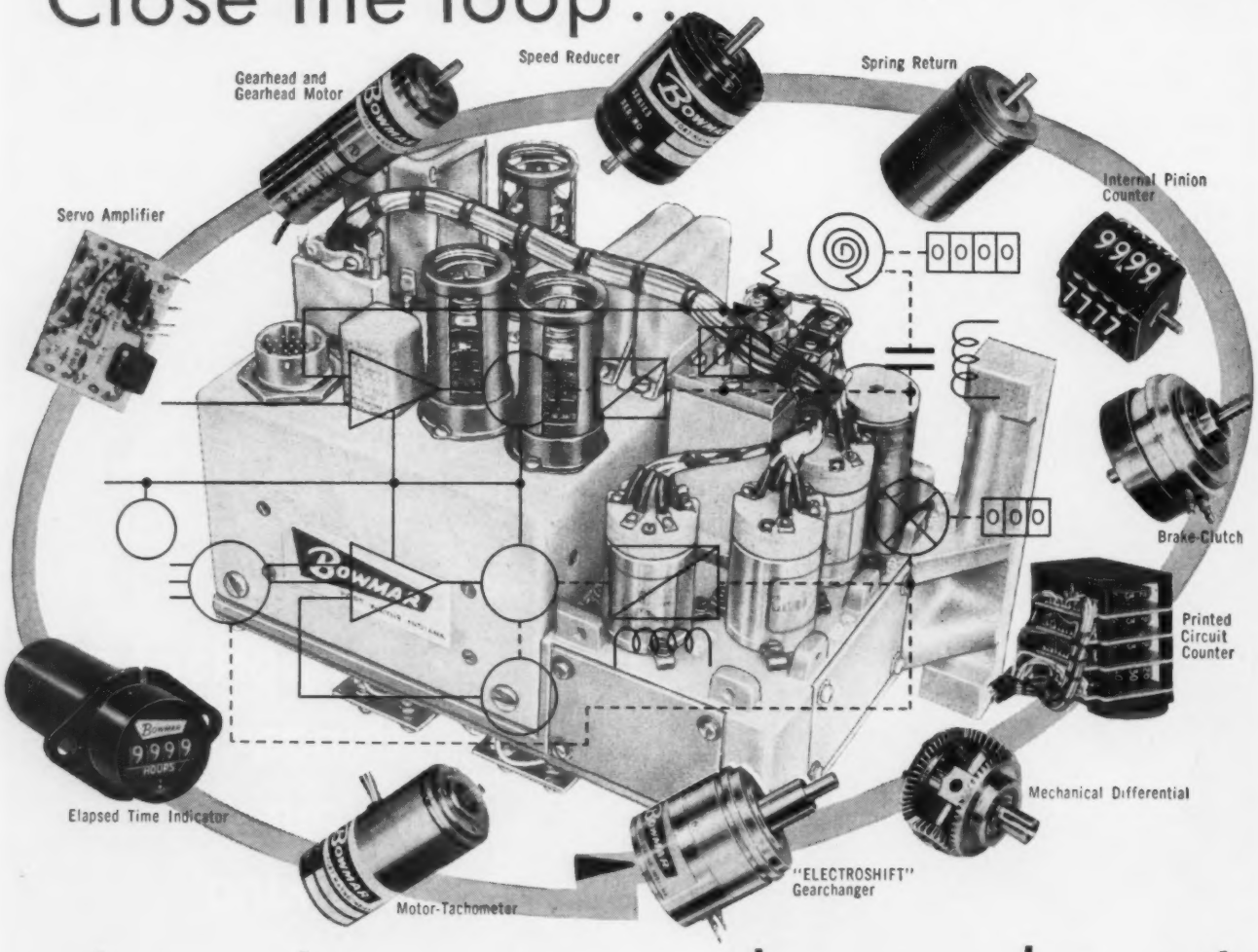
Close the loop . .



buy the part or the package!

- **PRECISION MECHANICAL DEVICES**
- **PRECISION COUNTERS AND INDICATORS**
- **PRECISION TIMING AND PROGRAMMING DEVICES**
- **PRECISION ELECTROMECHANICAL DEVICES**
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You get "ONE STOP" capability in all phases of precision control and indication from Bowmar. This capability is available for design and production of all types of standard or specialized precision COMPONENTS. With equal facility Bowmar can engineer and integrate these devices into complete SERVO PACKAGES.

Inventive miniaturization, further weight reduction and increased reliability can be part of the benefits to your precision control or indicating systems.

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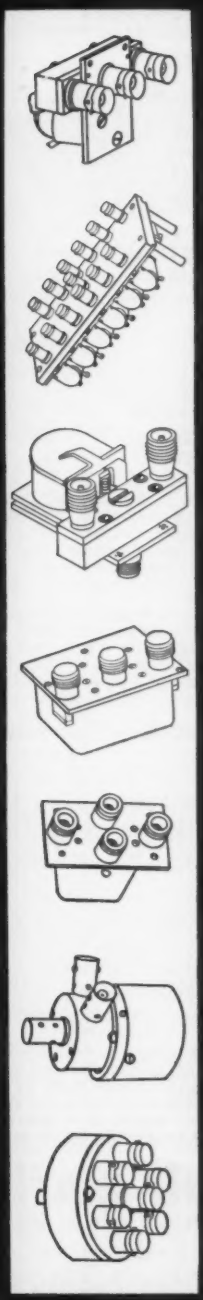
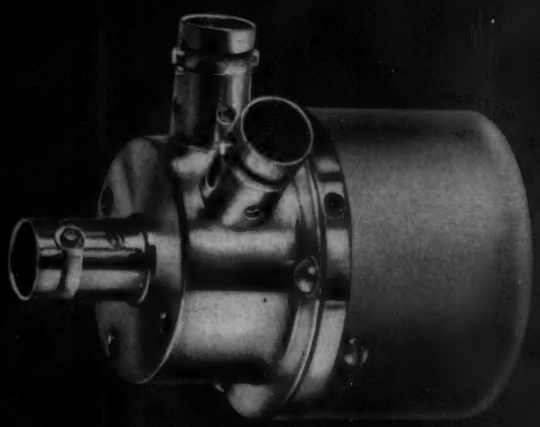
RF PRODUCTS BUILDS ANVIL RUGGEDNESS INTO PRECISION DK COAXIAL SWITCHES-RELAYS...

Spring-leaf switching blades, gold-plated silver contacts and impedance matched connectors keep insertion loss and VSWR (1.3 @ 4,000 MCs) low, Crosstalk high (in decibels down). Electro-mechanically actuated models operate and release in 8 to 20 milliseconds, depending on type and function, with a proven mechanical life of 1,000,000 cycles minimum when operated under 10 cps. / Available for fast delivery from factory stock in a large variety of configurations and functions, including SPDT, DPDT, 1P4T, 1P6T, 1P12T and Transfer types.

A DIVISION OF AMPHENOL-BORG ELECTRONICS **RF PRODUCTS** AMPHENOL DANBURY CONN. ipc DK



...AND DELIVERS IN 7 DAYS
100% tested from factory stock

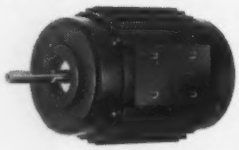


Get full details! Send for catalog DK61.

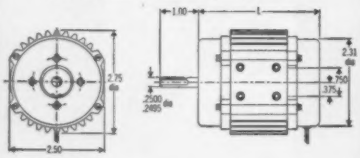
CIRCLE NO. 9 ON INQUIRY CARD

AC

Thousands of these precision motors from Air Marine have been used both by the military and industry. The "E Frame" shown below is offered in either induction or hysteresis synchronous versions.



"E FRAME" (Finned)
3.68" Overall Length
For Continuous Duty Application



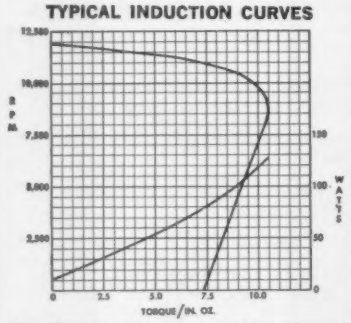
Induction

200 V., 3 phase 400 cycle
1/10 H. P. at 10,500 RPM
Torque, Starting 7.3" oz.
Torque, Running 9.0" oz.
Insulation to specs.

Hysteresis

115 V., 1 phase 400 cycle
Sync. Speed 8000 RPM
Starting Torque 3.0" oz.
Pull-in Torque 2.6" oz.
Pull-out Torque 2.7" oz.
Locked Rotor Current .92 amps

TYPICAL INDUCTION CURVES



Air Marine offers a complete line of fractional AC motors, blowers and fans. Motors range in size from 1/1000 to 1/2 H. P. 400 cycle units are designed for airborne application. Specify your needs and let Air Marine deliver.

air marine motors, inc.

369 BAYVIEW AVENUE
AMITYVILLE, L. I., N. Y.

2221 BARRY AVENUE
LOS ANGELES, CALIFORNIA

CIRCLE NO. 10 ON INQUIRY CARD

Top Two Together

Complete Line Now Available

Air Marine Motors of Amityville, New York and Motordyne of Los Angeles, California have combined to offer industry an extensive line of both AC and DC motors in the fractional horsepower range. Motors from these companies have for years fulfilled the requirements of both industry and military. The wide variety of types offered makes this source invaluable to the design engineer. Comprehensive literature on units to fulfill specific needs is available from either the east or west coast facilities.

Quality is a Statistic

Motors from Air Marine and Motordyne have gained a reputation of reliability based on the quality of performance. Numerous units designed for the military have continually met rigid environmental requirements. Hundreds of pages of statistics are available to establish beyond any doubt the ability of these motors to meet all types of specifications.

Research and Development

Laboratories are maintained on both the east and west coasts, under the direction of highly competent engineers who continually probe for more advance techniques in the manufacturing of rotating components. The AC and DC motors of these corporations are continually being studied to increase their life and efficiency. These laboratories also study specific problems of customers relative to motor performance.

Engineering Consultation

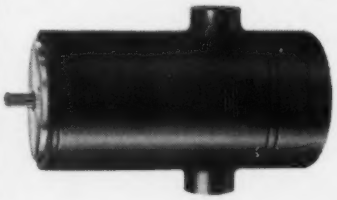
The field engineers of Air Marine and Motordyne are trained to assist the customer in the selection and installation of motors. These engineers are often called upon by the customer to assist in specifying the right motor for a specific job. A call to either the east or west coast facility will alert these engineers to your specific problems.

Additional Lines from Air Marine and Motordyne

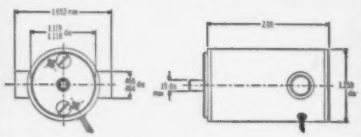
Now from these extensive facilities a complete line of blowers, fans, governors, breaks, gears, servo motors and thermal overload switches have become available: Complete information is available on request.

DC

Another precision motor from Motordyne capable of meeting the most stringent specifications. Hundreds of planetary gear speed reducers are offered as well as brakes, governors, clutches and thermal overload switches.



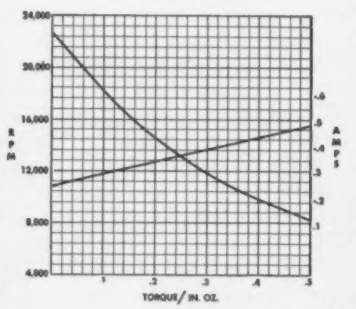
SERIES 1200, REVERSIBLE MOTOR



Power Supply	24-28 volts
Line Current	.5 Max. amps
Speed	10000 RPM
Output	.004 H. P.

Continuous Duty .5" oz.
Intermittent Duty 1.0" oz.

TYPICAL CURVE



If you face a DC motor application problem let a Motordyne field engineer assist in the solution. For prompt attention contact either the East or West Coast facilities.

MOTORDYNE INC.
a subsidiary of air marine motors, inc.

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LOS ANGELES, CALIFORNIA

369 BAYVIEW AVENUE
AMITYVILLE, L. I., N. Y.

CIRCLE NO. 81 ON INQUIRY CARD

CIRCLE NO. 11 ON INQUIRY CARD →

SPECTROL SOLVES EQUATIONS LIKE THIS...

$$\Theta = A\tan^{-1} B\left[\left(1+0.2\left[C+D\frac{e_o}{E_i}\right]^2\right)^{7/2}-1\right]$$

to design non-linear potentiometers –faster, more accurately

```
          AM     FPN-8,01,10          03366 11 03129 00001
          TF     *+18,KOUNT4          03378 26 03396 03952
          TFM    ,70,10               03390 16 00000 00070
          B      NEGK                 03402 49 03318 00000
EQUALK    AM     KOUNT4,02,10         03414 11 03952 00002
          TF     *+18,KOUNT4          03426 26 03444 03952
          TFM    ,70,10               03438 16 00000 00070
          TF     *+30,KOUNT4          03450 26 03480 03952
          TF     *+23,KOUNT5          03462 26 03485 03957
          TD     .                    03474 25 00000 00000
          AM     KOUNT5,01,10         03486 11 03957 00001
          CM     KOUNT5,FPN,7         03498 14 03957 03137
          BNH    EQUALK               03510 47 03414 01100
FLAGK     BNF    *+24,FPN             03522 44 03546 03137
          TDM    DECK+21,2,10         03534 15 03876 00002
          BB                          03546 42 00000 00000
POSK      MM     FPN-8,02,10          03558 13 03129 00002
          S      KOUNT4,99            03570 22 03952 00099
          TF     *+18,KOUNT4          03582 26 03600 03952
                                      03594 16 00000 00070
                 30,KOUNT4            03606 26 03636 03952
                 23,KOUNT5            03618 26 03641 03957
                                      03630 25 00000 00000
                 4,02,10              03642 11 03952 00002
                 NT5,01,10            03654 11 03957 00001
                 KOUNT5,FPN,7         03666 14 03957 03137
          BNH    *+96                 03678 47 03774 01100
          CM     KOUNT4,DECK,7        03690 14 03952 03855
```

The above equation is the mathematical expression for the non-linear function required of a precision pot to relate voltage ratio $\frac{e_o}{E_i}$ to potentiometer shaft position Θ.

This is a typical non-linear problem applied to Spectrol's new IBM 1620 digital computer . . . equipment which eliminates days of design time, provides error-free results and makes it possible for Spectrol to issue quotations a day or two after receiving your request. For the past three years Spectrol—and only Spectrol—has used this technique.

Basically, it works this way: Computer input data is in the form of programmed equations or tabulated X and Y coordinates. Previously programmed tapes with general equations for non-linear applications (on file at Spectrol) operate on the data, to compute output in terms of winding equipment settings, cam angles and radii. An electric typewriter prints out this information on a form such as that shown above, which is sent directly to production, eliminating delays and potential transcription errors.

Speaking of production, Spectrol has precision equipment for winding non-linear resistance elements at its plants in New York and Toronto to supplement its California facilities. Using the computer in California, Spectrol can TWX winding instructions to either plant . . . another reason you can expect results sooner.

One more thought: Call us if you're in a bind. Letters take time.

To assist engineers who have applications for non-linear pots, Spectrol has prepared a detailed specifications brochure. For your copy, contact your Spectrol engineering representative or the factory.

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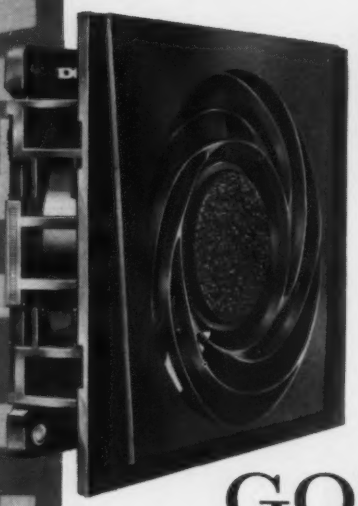

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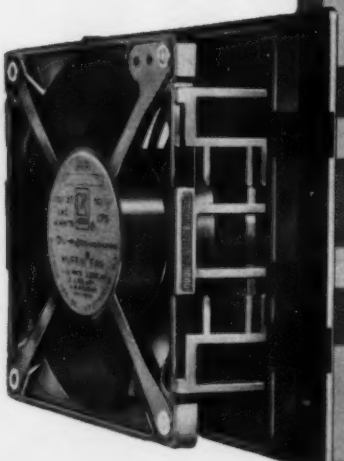

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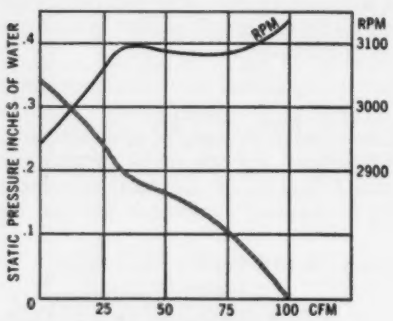

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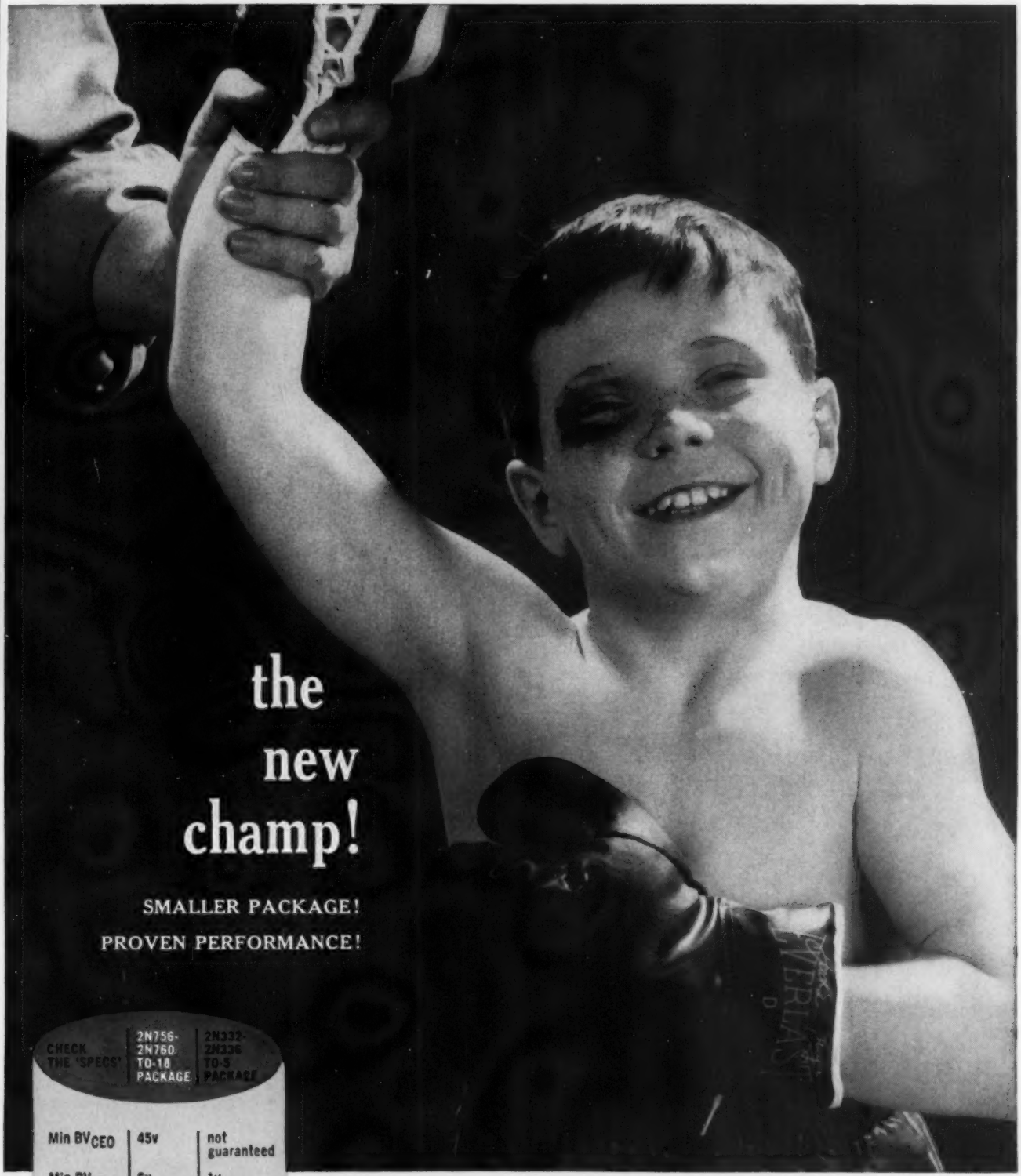

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FILTERS FOR SERVO MODULATORS AND DEMODULATORS

By Martin Glasberg, Contributing Editor

Notch Filters Reject Unwanted Frequencies Without Influencing Servo Information

Modulators and demodulators are often an important part of a servo. Ideally, a modulator would take dc and convert it to ac, at the carrier frequency, no matter how fast the dc were changing. An ideal demodulator would be just the reverse: it would convert the amplitude or envelope of a modulated signal into a dc signal. The modulator is commonly employed in an ac servo to convert a dc error signal into a modulated signal to drive the servo motor. In the same way a demodulator is used to convert ac error signals in a dc servo. One type of ac servo uses both a modulator and demodulator to convert the normal modulated signal to dc, which can be acted upon by a dc compensation network, and then to convert the resulting dc signal back to ac.

In general, modulators and demodulators are made-up of two functional elements, as in Fig 1: a converter and a filter. Great emphasis has been placed on the converter, while the filter has been given relatively little attention. Filters, of course, have been widely studied, but primarily for other applications. The filter in this case must be very carefully chosen because introduction of large phase shift at certain frequencies greatly reduces the performance of the resulting servo.

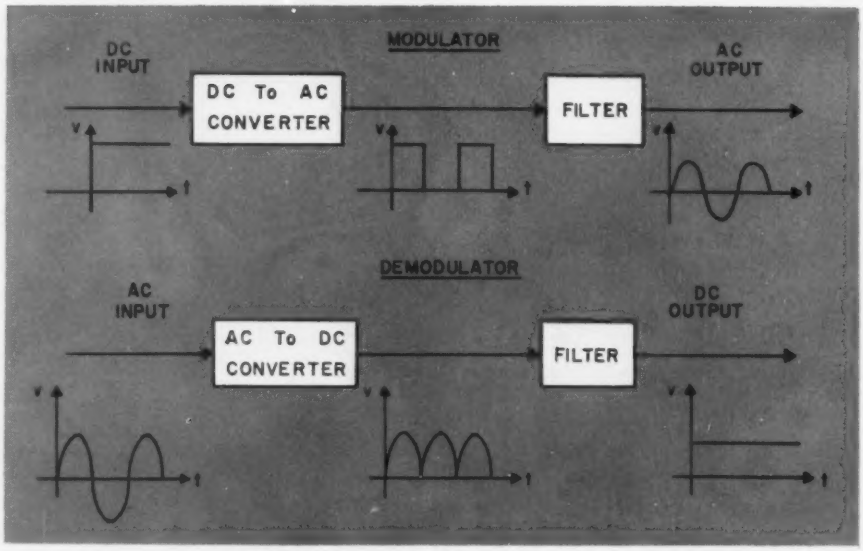


Fig 1 Modulator and demodulator block diagrams.

FILTER PROBLEMS

Figure 1 shows that the modulator filter must eliminate all frequency components in its input except the carrier frequency and/or the sidebands of the modulated signal. The demodulator must eliminate all frequency components in its input except dc and/or the information frequencies. The idea of introducing minimum phase shift and attenuation at the information frequencies or pass band of the servo is very important. It makes the difference between normal filters and a servo filter. The servo filter must reject unwanted frequency components generated by the converter but it must not influence the servo information carried by sideband components in the modulator or the varying components of dc in the demodulator. Obviously there will be a compromise between good filtering and good servo performance in designing a filter, but this compromise will be less than ideal without a good knowledge of the unwanted frequencies that must be rejected.

UNWANTED FREQUENCY COMPONENTS

Figure 2 shows the Fourier analysis of the three most common waveshapes generated by servo modulator converters. Case 1 is an ideal switch; this case can be approached with very fast transistors. In practice the rise time of the switch will not be perfect, as in Fig 2, but the frequency components generated by typical transistor rise times would be high enough to neglect. There are not too many unwanted components in this case and the closest component to the carrier frequency, ω_c, is at $3\omega_c$. This means that the filter has room to cut-off above ω_c and still attentuate greatly at 3 ω_c.

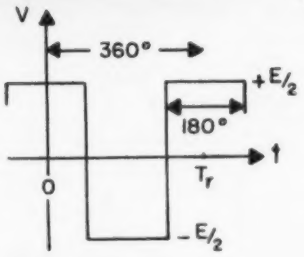
Case 2, Fig 2, is typical of simple mechanical choppers whose dwell angle is not 180° because it takes time to switch from one contact to another. Note that in this case there are a great many unwanted components and it obviously would be harder to filter this waveshape.

Case 3 is also a chopper but one having the chopper transferring from contacts at a zero output voltage. This waveshape has components quite similar to that in case 1 and would result in a better modulator.

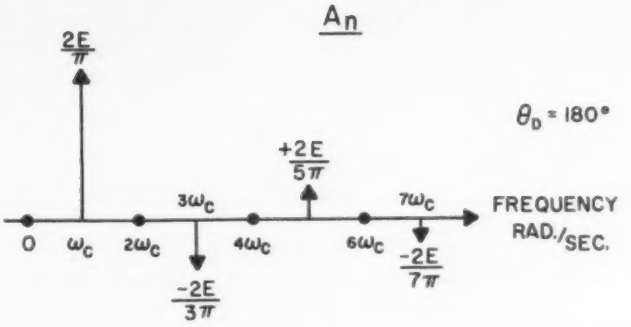
The moral to this story is that it might pay to use some care in chosing a converter so as to make the filter's job more effective.

Figure 3 shows the Fourier analysis of the three most common waveshapes

CASE (1)



$$\omega_c = \frac{2\pi}{T_r}$$

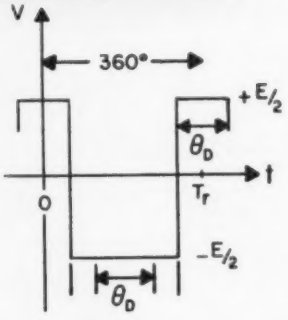


$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos n\omega_c t$$

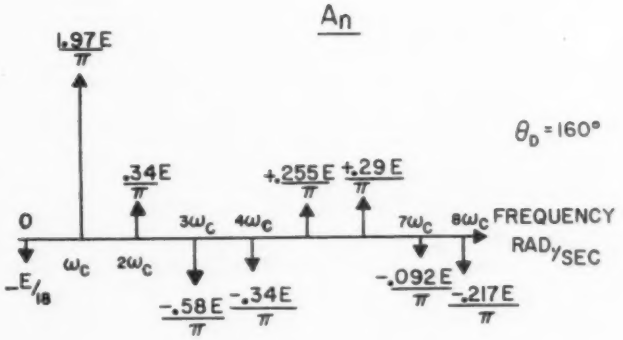
$$A_0 = 0$$

$$A_n = \frac{2E}{n\pi} \sin(n90°)$$

CASE (2)



$$\omega_c = \frac{2\pi}{T_r}$$

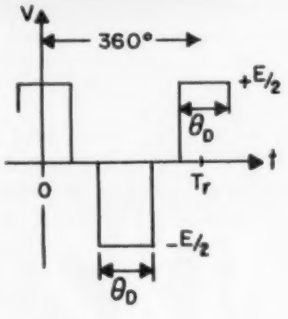


$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos n\omega_c t$$

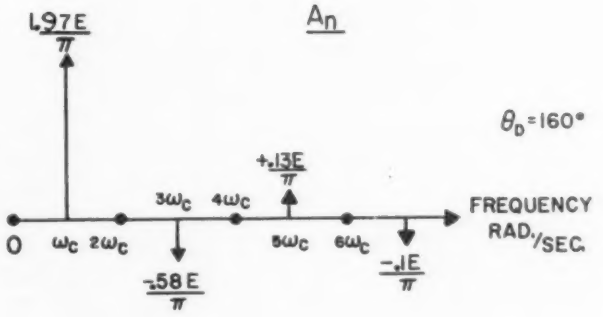
$$A_0 = \frac{E}{2\pi}(\theta_D - 180°)$$

$$A_n = \frac{2E}{n\pi} \sin\left(\frac{n\theta_D}{2}\right)$$

CASE (3)



$$\omega_c = \frac{2\pi}{T_r}$$



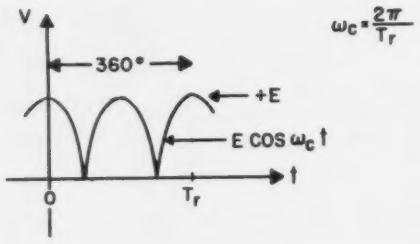
$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos n\omega_c t$$

$$A_0 = 0$$

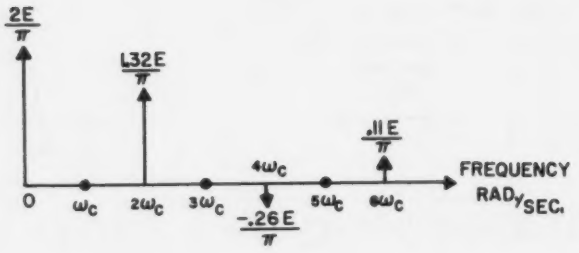
$$A_n = \frac{E}{n\pi}\left[\left(\sin\frac{n\theta_D}{2}\right)1 + \cos(n)(180°-\theta_D) + \left(\cos\frac{n\theta_D}{2}\right)\sin(n)(180°-\theta_D)\right]$$

Fig 2 Common dc to ac converter waveforms.

CASE 1



$\omega_c = \frac{2\pi}{T_r}$



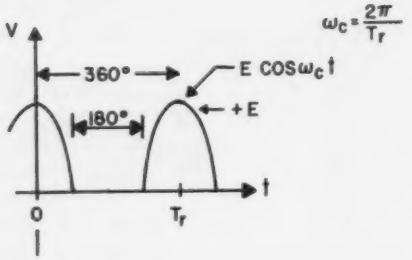
$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos 2n\omega_c t$$

$$A_0 = \frac{2E}{\pi}$$

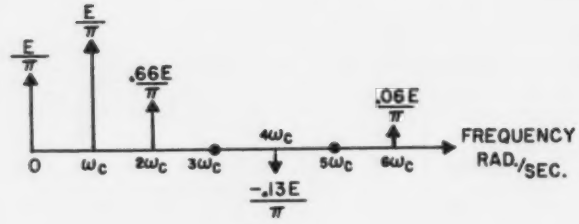
$$A_n = \frac{-2E}{\pi}\left[\frac{1}{1-2n} + \frac{1}{1+2n}\right]; \text{n ODD}$$

$$A_n = \frac{+2E}{\pi}\left[\frac{1}{1-2n} + \frac{1}{1+2n}\right]; \text{n EVEN}$$

CASE 2



$\omega_c = \frac{2\pi}{T_r}$



$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos n\omega_c t$$

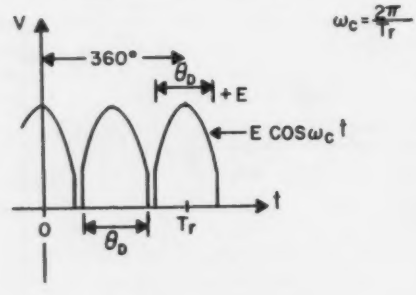
$$A_0 = E/\pi \; ; \; A_1 = E/2$$

$$A_n = 0 \; ; \; \text{n ODD}$$

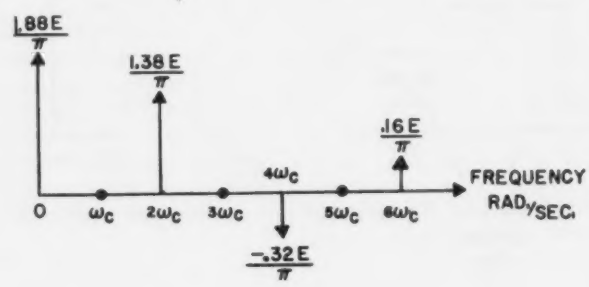
$$A_n = \frac{E}{\pi}\left[\frac{\text{SIN}(1-n)\pi/2}{(1-n)} + \frac{\text{SIN}(1+n)\pi/2}{(1+n)}\right]; \text{n EVEN}$$

CASE 3

LET θ_D = 160° AS IN COMMON MECHANICAL CHOPPER



$\omega_c = \frac{2\pi}{T_r}$



$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos n\omega_c t$$

$$A_0 = \frac{2E}{\pi}\cos\frac{(180° - \theta_D)}{2}$$

$$A_n = \frac{2E}{\pi}\left[\frac{\cos(1-2n)\frac{(180°-\theta_D)}{2}}{(1-2n)} + \frac{\cos(1+2n)\frac{(180°-\theta_D)}{2}}{(1+2n)}\right]; \text{n EVEN}$$

$$A_n = \frac{-2E}{\pi}\left[\frac{\cos(1-2n)\frac{(180°-\theta_D)}{2}}{(1-2n)} + \frac{\cos(1+2n)\frac{(180°-\theta_D)}{2}}{(1+2n)}\right]; \text{n ODD}$$

Fig 3 Common ac to dc converter waveforms.

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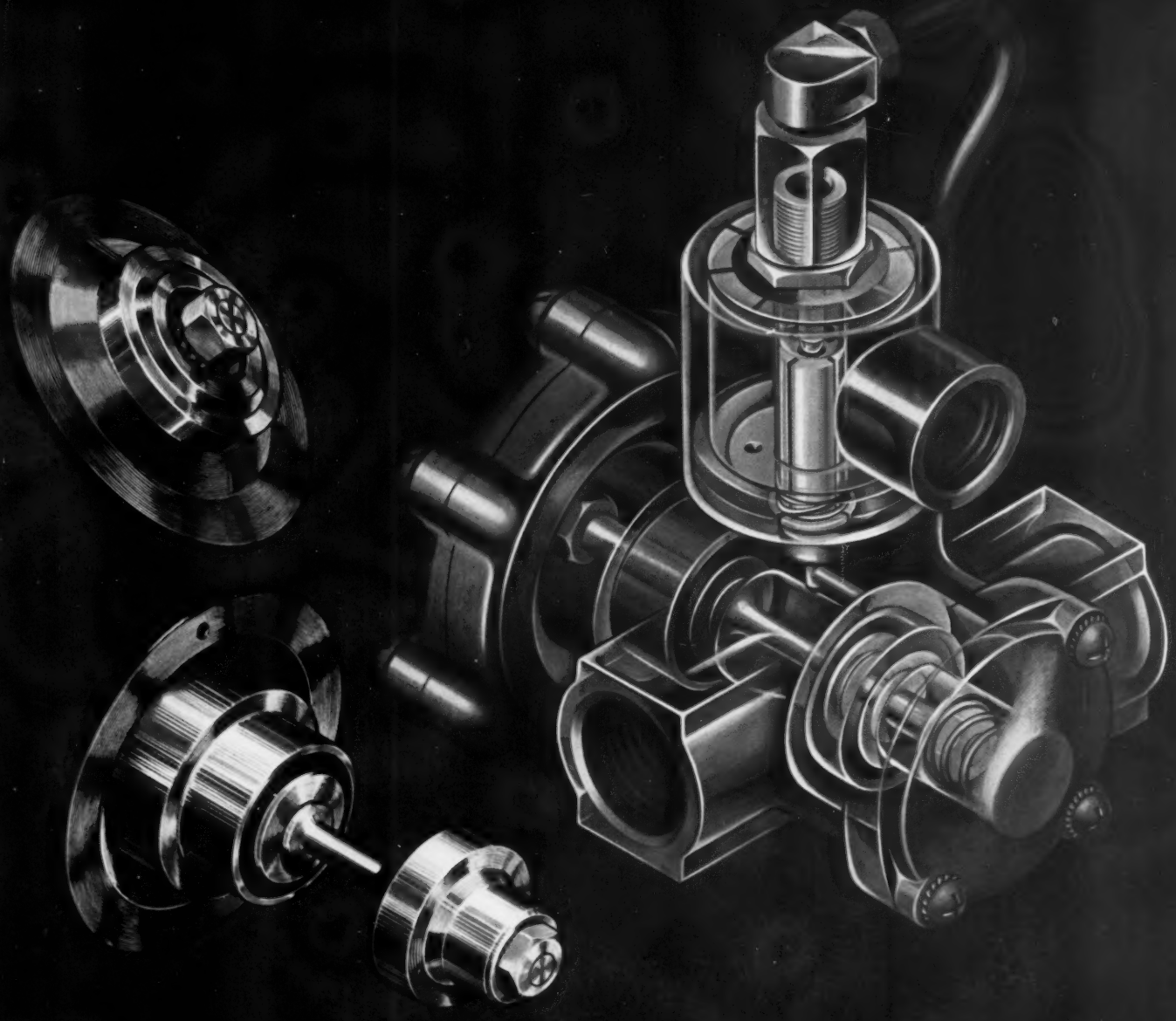

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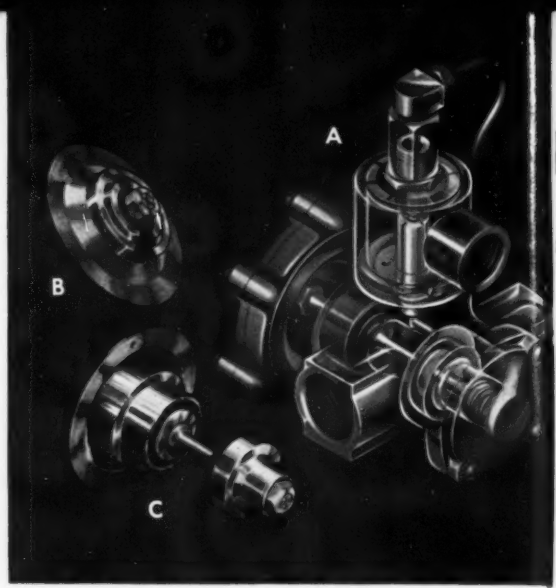
for high flow, heavy-duty industrial use

Skinner combines unique diaphragm assembly and V5 solenoid operator in new L Series valves

Skinner has now combined its famous V5 solenoid operator with a unique diaphragm assembly in a new line of two-way and three-way valves—the versatile L Series.

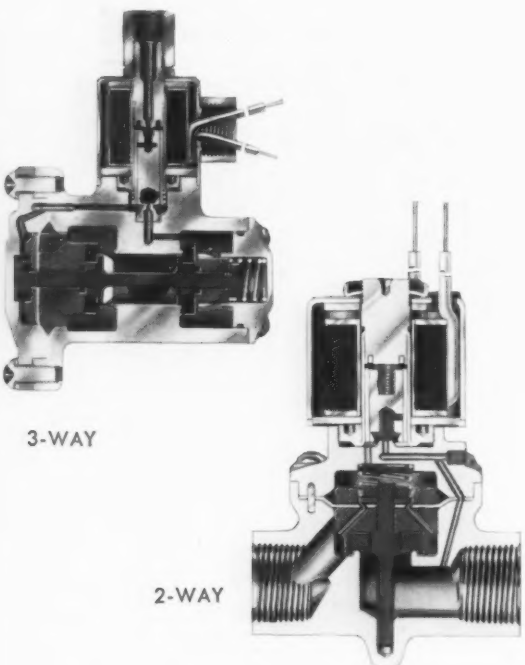
Unusually long life is assured by this new diaphragm assembly. The 3-way diaphragm consists of two tough laminates of nylon fabric coated with a Buna-N rubber separated by a thin Teflon disk. The assembly is virtually 100% supported in the open and closed positions with only a very small area exposed to pressure differential during operation. Life tests show that this type of diaphragm far out-performs all others tested.

The two-way diaphragm and spindle assembly supports a seal retainer and soft, synthetic seal which provides bubbletight sealing of the main orifice. This seal fits on a shoulder which extends beyond the seat and helps to cushion the closing motion—thus minimizing water-hammer.



A—Transparent view of normally closed 3-way solenoid valve
B—Front view of diaphragm assembly
C—Spindle seal retainer and diaphragm assembly

Low cost 2-way and 3-way valves to meet your high flow industrial requirements



Cutaway views of 2-way and 3-way valves showing how the unique diaphragm assembly and solenoid operator are combined in these new valves.

Skinner L Series solenoid valves feature forged naval brass bodies, stainless steel and brass internal parts. They are available normally closed, normally open and directional control in standard and explosion-proof construction.

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All 3-way and 2-way normally open valves are supplied with a piped exhaust return. For catalogs and complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

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Pipe Sizes, NPTF		⅜"*, ½", ¾", 1"	⅜", ½", ¾"
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Operating Pressure Differential	Minimum	5 PSI	5 PSI (⅜" 10 PSI)
	Maximum	150 PSI	150 PSI
Position		Normally closed, Normally open	Normally closed, Normally open, Directional control
Leakage		Bubbletight	Bubbletight
Temperature Range (Ambient and Media) *has ½" orifice		Minus 40°F to plus 180°F	Minus 40°F to plus 180°F

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Skinner solenoid valves are distributed nationally.

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generated by servo demodulator converters. Case 1 is again an ideal switch, case 2 is a half wave converter and case 3 is a full wave converter using a chopper with less than 180° dwell. The results are similar to those experienced with the modulator converters and the same moral would apply.

TYPES OF FILTERS

In general there are three types of filters which could be used in servo modulators and demodulators: low pass, bandpass and notch. The low pass filter, ideally, has no attenuation (zero insertion loss) below a cut-off frequency and infinite attenuation thereafter. The bandpass filter, ideally, has the same characteristic as the low pass but it has a lower cut-off frequency so that only frequencies in a certain range or band are not attenuated. Notch filters, however, attenuate at only one frequency or only in a limited region around one frequency.

The problem with low pass and bandpass filters is that to make them attenuate sharply at their cut-off frequencies, large phase shifts must be experienced at the information frequencies. Notch filters with reasonably high Q's, on the other hand, will attenuate sharply at one frequency without introducing appreciable phase shift at lower frequencies. The notch frequency, however, is set for a particular frequency which, if it changes or if the filter drifts through age, will affect the resulting output waveshape. Sharp low pass and bandpass filters also require a number of tuned stages while a notch filter is made-up of one tuned stage or, in the case of a "twin T", of only resistors and capacitors.

Based on the previous outline, notch filters appear most satisfactory. Bandpass and low pass filters should be reconsidered for systems which require low sensitivity to carrier frequency changes and component ageing and allow for the added complexity and lower bandwidth.

Actually the notch filter must be accompanied by a rather flat low pass filter to attenuate the small higher frequency components, as seen in Figs 2 and 3. The cut-off frequency of this filter can be set quite high and only one tuned stage or a simple RC need be used, so as to produce very small phase shift at the information frequencies. In practice this filter's ability to reject the small higher frequency components, after the notch takes out the one generally large unwanted component, will determine how perfect the waveshape

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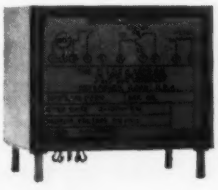
Stepping devices from A. W. Haydon Co. can do wonderful things to pulses ...with pulses...and for pulses. For instance, one precision gated stepping switch acts as a pulse divider for a random or variable pulse source—or as a frequency divider if the pulse source is constant. Another works in conjunction with pulses, supplying single or multiple switch closures with an accuracy virtually equal to that of the pulse source itself. Still a third will count a predetermined number of pulses, rotate a stepper switch, return the counter to 000, and cut off the pulse source. ■ The remote positioning device illustrated is but one of A. W. Haydon Company's fancy steppers. Here a precision gated stepper switch has been coupled to a synchro transformer. Similarly, precise angular positioning of rotary components such as potentiometers, dials and indicators can be controlled. Based only on the number of pulses received (not incremental changes in voltage or phase angle), it will hold a set position whether power is on or off, and will home the synchro to the zero reference on demand—ready to accept another setting. ■ All A. W. Haydon Co. stepper motors are all-electric—no ratchets, linkage, contacts or other mechanical crutches are used. Their power consumption is low, accuracy is extremely high. ■ Send for technical brochure SP9-1 and find out more about pulse driven steppers and their application.



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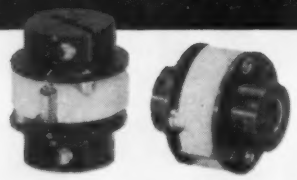

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Type MPC-1 consists of two flanged aluminum hubs and nylon or Delrin discs with V-grooves that are displaced 90° with each other. Discs are fastened with stainless steel springs loading ball pivots against V-grooves. Dimensions ⅞ x ⅞ in.
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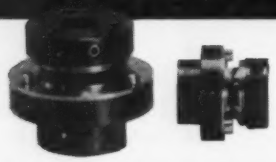
ADJUSTABLE SLIP CLUTCHES



FEATURE • Adjustment over a wide torque range • Compactness and lightweight

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Both are constructed of aluminum hubs, Delrin* on stainless steel clutch plates and stainless steel hardware. These rugged, high performance clutches are friction units to protect components against excessive or inertia shock loads. Range of bores to accept shafts from .120″ to .250″. These clutches meet MIL-E-4970 specs.
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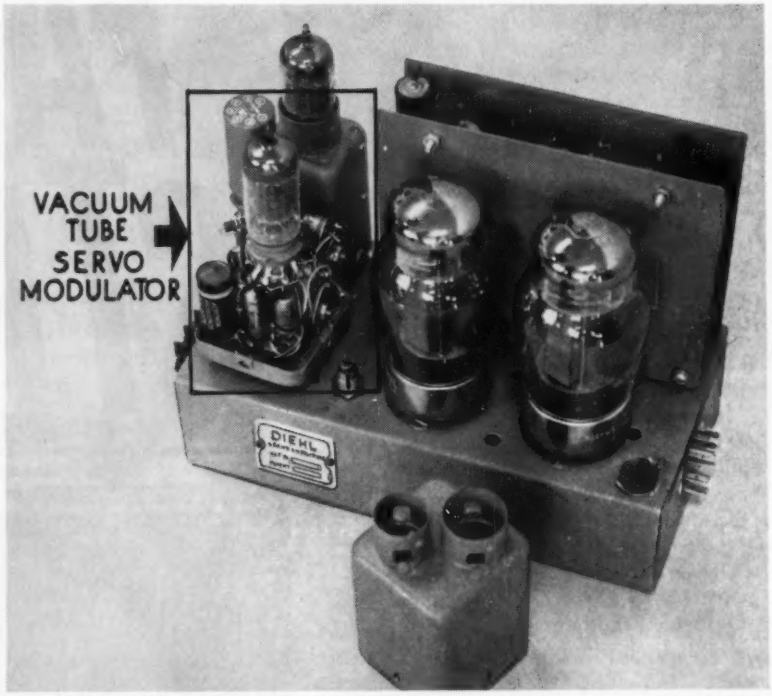

Fig 4 Picture of Diehl servo modulator plugged into power amplifier VAO75-OA-100. Specifications: Gain about 1 volt rms/1 volt dc, input impedance 100 K ohms, output impedance 6.5 K ohms, phase shift less than 10 degrees over a passband of 20 cps (using 0.1 μfd), maximum output signal 1 volt rms, percent total harmonic distortion is about 5% (using 0.1 μfd).

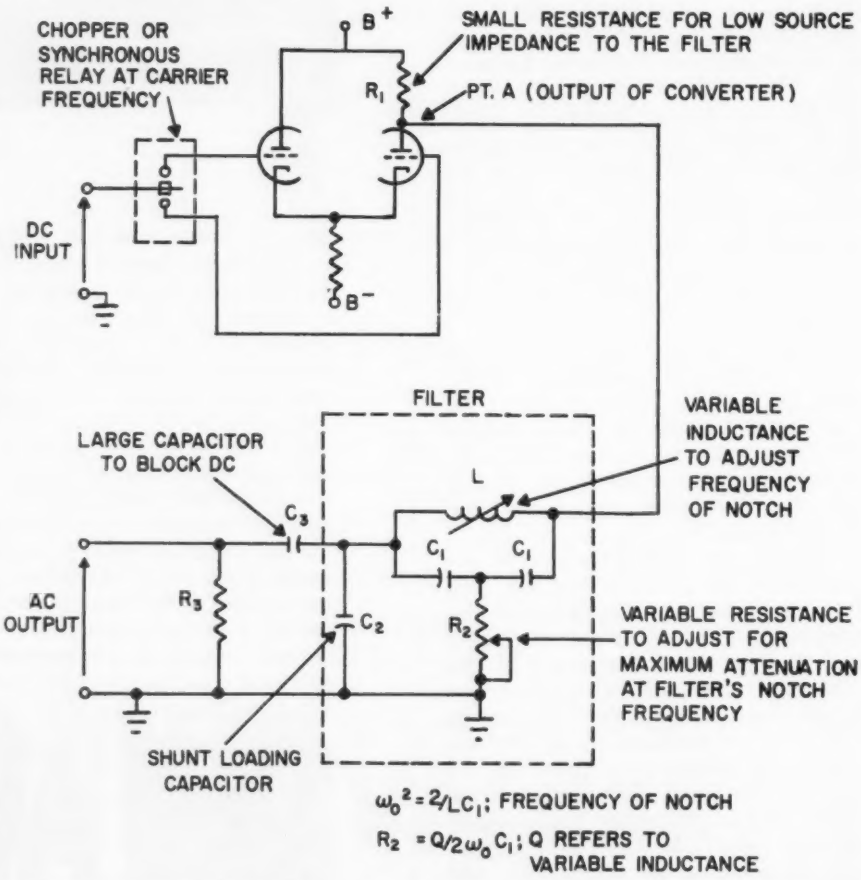

Fig 5 Simplified schematic of Diehl Mfg. Co. vacuum tube modulator.

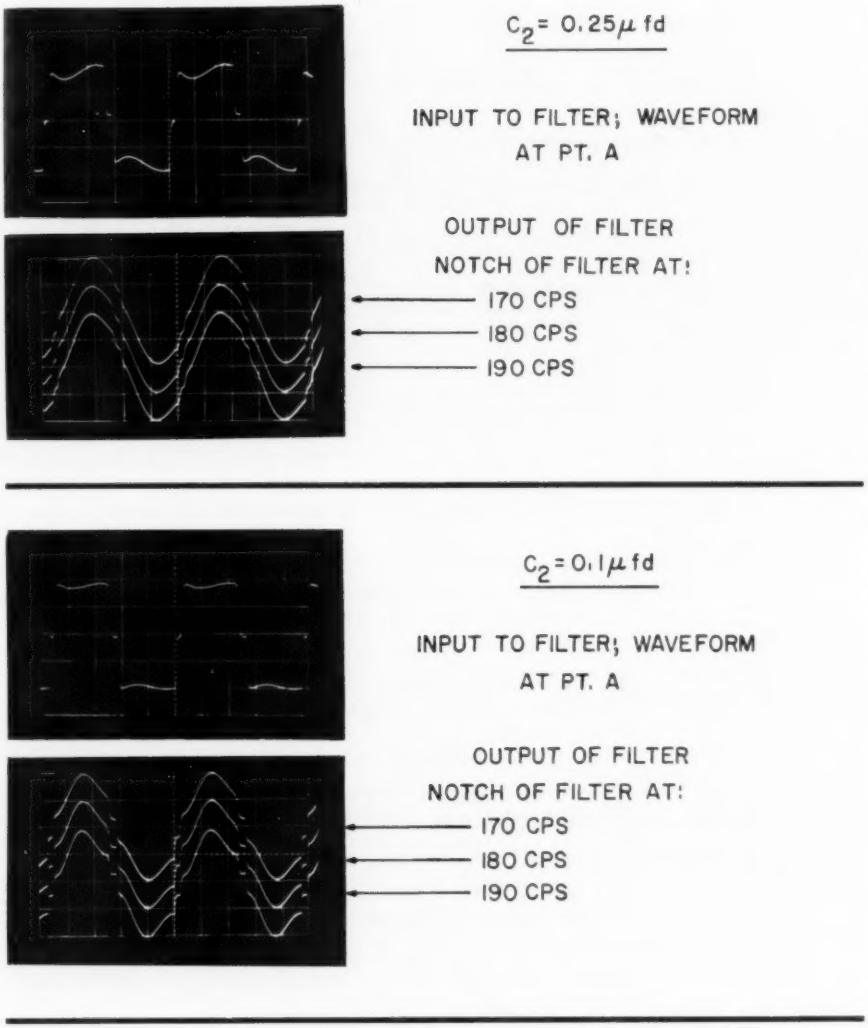

Fig 6 Waveforms through filter and the effect of changes in notch frequency on the resulting output.

looks to the eye. The servo motor, however, will generally be less sensitive to these higher frequency components.

EXAMPLE

An example of the approach described above can be taken from the Diehl Mfg. Co.'s vacuum tube plug-in modulator, used with their VA075-OA-100 Servo Power Amplifier (Fig 4). Figure 5 is a simplified schematic of the Modulator. It notes a number of features:

- A differential amplifier arrangement was required to get the desired converter waveform – see case III, Fig 2.
- A low source impedance, desired for the filter, is obtained at the sacrifice of gain. This is also the reason for putting the dc blocking capacitor after the filter.
- A variable inductor and resistor are use in the bridge T to obtain the best and most accurate null.

WAVESHAPE AND HARMONICS

Figure 6 shows the waveform of the converter, at point A in Fig 5, as well as the output waveform. The waveform of the converter is not exactly the same as the waveform analyzed in case III, Fig 2, because of the filter loading, but the harmonic measurements, from Fig 7, show that the main components are almost the same as those in Fig 2. There are three output waveshapes in Fig 6 for three settings of the bridge-T notch frequency: 170, 180 and 190 cps.

SOLUTION TO ROTARY SOLENOID PROBLEMS

The model 8 RS 610, one of the smallest units of its type known to the industry, is typical of a new line of **imc** rotary DC solenoids available in sizes from ¾", to 3⅛" in diameter (sizes 8 through 32), stroke lengths of 5° to 60°, cw or ccw rotation, and with operating voltages from 6 to 300 VDC; available with or without switching mechanisms.

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SPECIFICATIONS—MODEL 8 RS 610

VOLTAGE:	28 VDC
POWER:	50 watts
RATED TORQUE:	8.5 ounce-inches
STROKE:	30°
DUTY CYCLE:	Maximum "on" time 5 seconds Minimum "off" time 50 seconds
RETURN SPRING:	½-1 ounce-inch, minimum
TORQUE CONSTANT:	260 ounce-inch—degrees
WEIGHT:	1.5 ounces
SIZE:	¾" diameter

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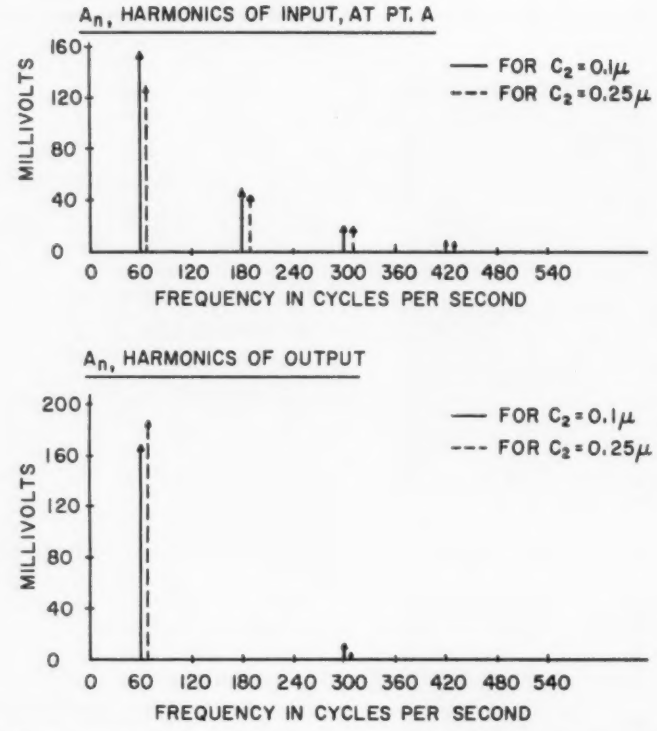

Fig 7 Harmonic measurement of the waveforms in Figure 5. These measurements were taken with the notch of the filter tuned to 180 cps.

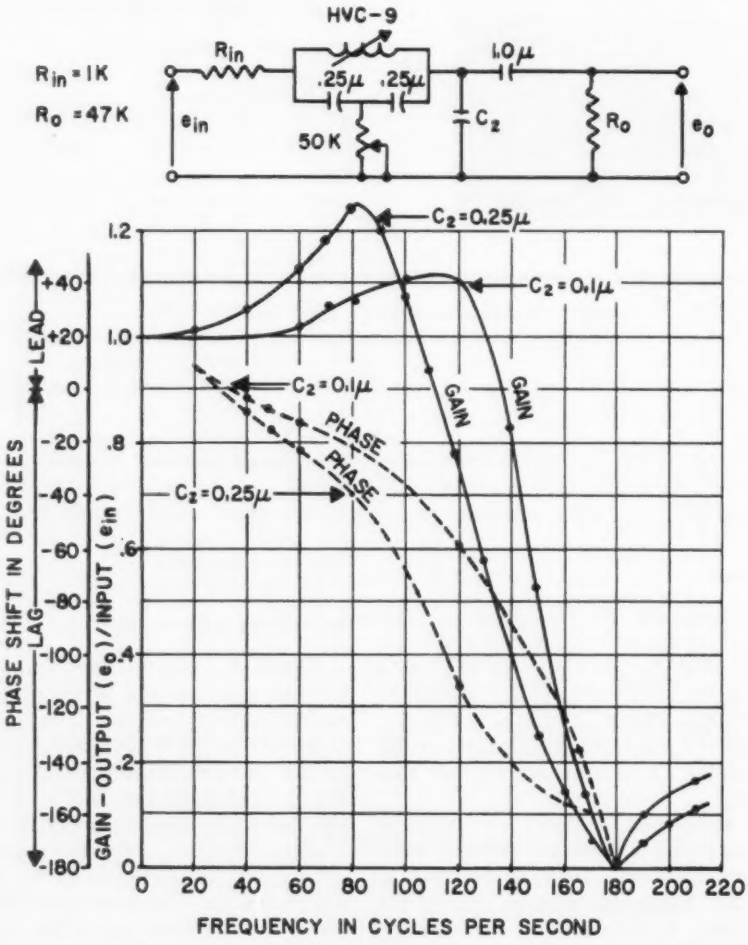

Fig 8 Gain and phase shift of capacitor loaded "Bridge-T" filter.

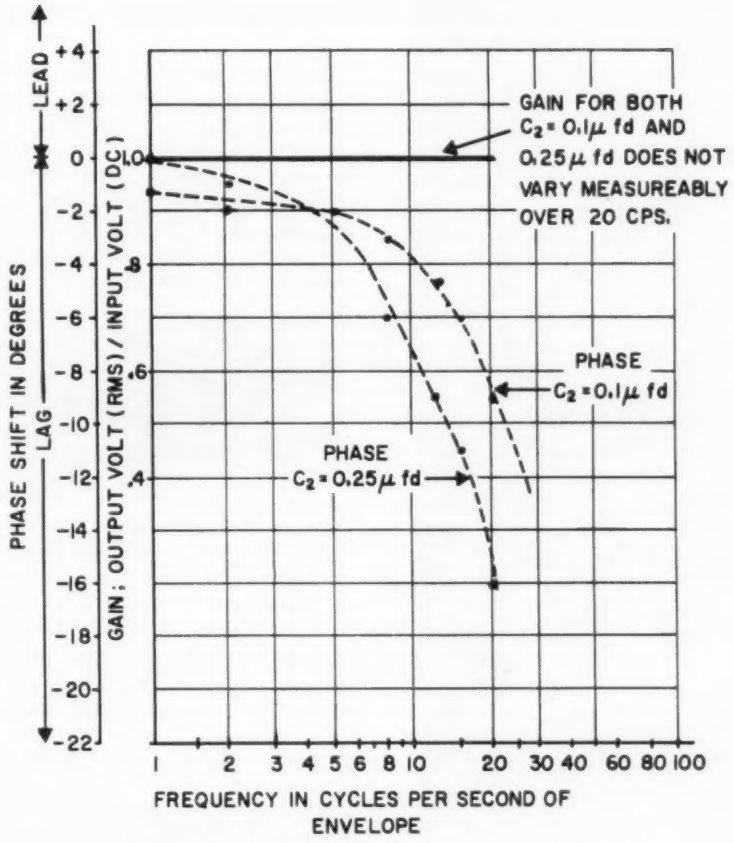

Fig 9 Frequency response of Diehl modulator; dc input to suppressed carrier amplitude modulation output.

No appreciable distortion occurs, which means that variations in the line frequency can be easily tolerated. Fig 7 only shows the harmonic content of the waveforms for the filter set at 180 cps. There was, however, an increase of about 20 times in the 180 cps harmonic when the filter was set at either 170 or 190 cps, but the filter still produced a rather small 180 cps component, as can be seen from the actual waveshapes in Fig 6.

FREQUENCY RESPONSE

Figures 6 and 7 show two cases: C_2 at 0.25 μfd and 0.1 μfd. C_2 is the shunt loading capacitor on the bridge-T filter. Obviously, the larger shunt capacitor produces better filtering at high frequencies. Better filtering, however, must produce more phase shift around 60 cps and, consequently, produce a smaller bandwidth. The sinewave frequency response of the filter is drawn in Fig 8. It shows there is almost twice the phase shift at 60 cps using 0.25 μfd rather than 0.1 μfd as a shunt. The resulting servo or amplitude modulated frequency response, in Fig. 9, agrees with the response we could predict from Fig 8. • • •

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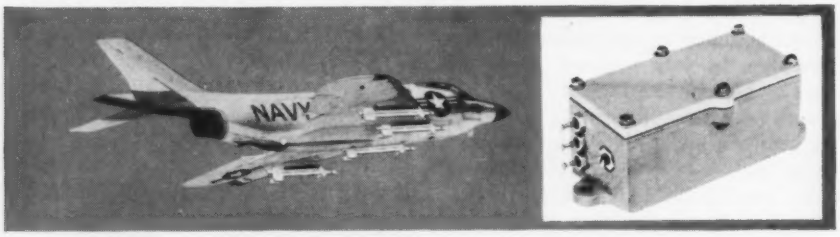

THANKS TO A FAIRCHILD ACCELEROMETER

When the pilot of this McDonnell F3H actuates the firing key, long slender heat-seeking U. S. Navy Sidewinders streak from their wing racks — track down and demolish even the most devious enemy.

A compact fire control computer — designed and produced by Hazeltine Corporation for the U. S. Navy — is located in the F3H fuselage after the cockpit. An important component in this computer is a FAIRCHILD TA-100 ACCELEROMETER.

Specifically designed for applications that require measurement of missile or aircraft maneuvering accelerations, the TA-100 is oriented in the F3H to sense accelerations in a plane normal (perpendicular) to the major axis of Sidewinders in their racks. Excessive G's in this plane — caused by intricate, high-speed air tactics — could divert Sidewinder from finding its target. When this condition exists, the TA-100 accelerometer causes a warning light to flash on the pilot's instrument panel — advises him to correct aircraft performance before firing.

Fairchild TA-100 Accelerometer (Type 940) is only 2½" x 1 13/16" x 1 5/32", measures sustained accelerations from 0 to ±¼ G to 0 to ±50 G. A pendulous device, it consists of a mass supported on a torsion type spring and a precision potentiometer whose wiper is actuated by the mass. Electrical output is directly proportional to linear acceleration. Oil-filled, the damping factor is held within close tolerances through −55° to +100°C. Overall accuracy — including linearity, hysteresis and repeatability — is better than 1%.

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COMPONENTS DESIGN

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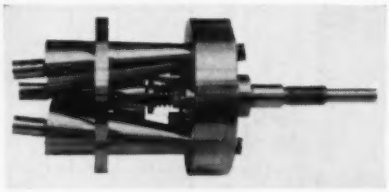
Change of speed, in a new miniature transmission, requires a relatively large movement of control members. This factor provides high accuracy by minimizing the effect of lost motion that is inherent in any control linkage. Shifting effort is sufficiently low to permit control by small servo motors in automatic control systems.



Graham Transmission, Inc., Menomonee Falls, Wisc. has designed three versions of the drive: one that delivers all speeds from any desired maximum to zero; another delivers speeds from maximum to zero and into full reverse without change of input rotation and a third, especially designed for speed correction, gives output speeds that vary approximately ±10% from a given input speed.

The non-rotating member of the drive is a traction ring that engages tapered rollers at varying diameters. Input shaft supports the carrier for the tapered rollers which are inclined at an angle equal to their taper, so that their outer edge is maintained parallel to the central axis. The traction ring is moved lengthwise about the rollers to change the speed. Required traction pressure between tapered rollers and the ring is obtained either through the centrifugal force of the rollers themselves, which press outwardly against the ring, or by a spring-loaded plug. A pinion at the end of each roller meshes with either a sun or ring gear fixed to output shaft.

Unlike disc and roller drives, where complete slip occurs if the load exceeds the available traction thereby wearing a spot on the contact parts, the differential action in the new drive prevents full slip and maintains lubricated contact even if the output shaft is stalled by overload. The transmission thus serves as an overload clutch as well as a speed variator and torque multiplier. Internal losses are reduced because pressure and side spin at the tractional contacts is at a minimum. Side spin is low because the rollers are internally intangent to the ring near the extreme diameter of the housing and the angle of roller inclination is only six degrees. The smallest number (3) of balanced contacts are used so as to insure equal load division.

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Raceway Parallelism with Side	.000020"	.000020"
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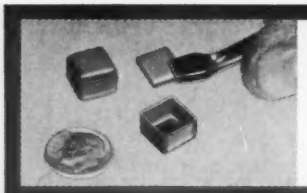
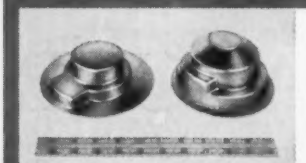


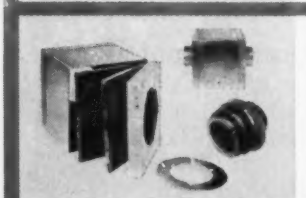
Micro miniature shield and cover, punch press operation.

Sequence of shield cans, punch press or spinning.

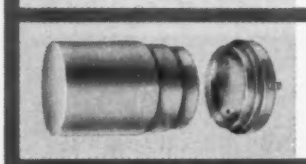


Complex configuration multi-lamina shield, hydroformed.

CRT shield illustrating combination of hand fabrication, spinning and sizing.

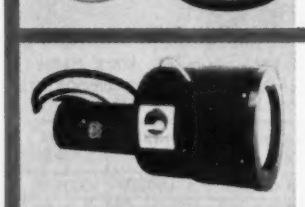


Backward wave tube shield assembly design, involving hand fabrication and hydroform or spinning.

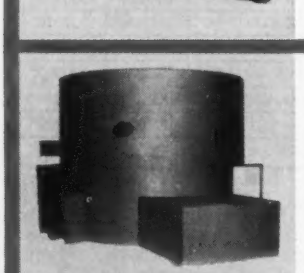


Special purpose shield, hand fabrication (levitated gyro).

Tape preserver can be spun, hydroformed or punch press fabricated.



Data storage tube shield, hydroform or spinning, plus hand fabrication.



Large fabricated special structure (shaker table shield), approx. 60" dia. and 57" high.

Composite photo demonstrating that magnetic shielding qualities of NETIC alloy material are not affected by vibration, shock, (including dropping), etc.

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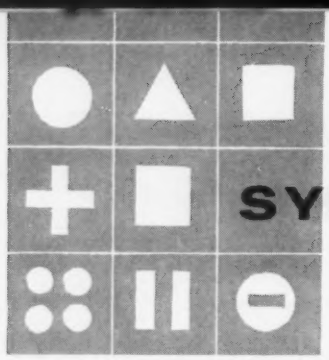

SYSTEMS DESIGN

ANTENNA MOUNT

By Oliver Phillips,
Chief Electronics Engineer,
TEMEC, INC., Van Nuys, Calif.

Scimitar Yoke Type Pedestal Designed For End Fire Array

Until recently the parabolic type of antenna has reigned supreme in the field of self-tracking radar systems. A continued interest in the frequency range below 2200 mc has brought into existence a type of antenna using an array of end fire elements mounted on a ground plain. While work has progressed to take full advantage of the capabilities of such an antenna, relatively little has been done in pedestal design to fully exploit the physical geometry of an end fire array. To this end Temec, Inc. has designed a pedestal to take full advantage of the antenna's geometry.

Three major problems face the pedestal designer: (1) structural resonances, (2) torque due to wind and (3) reflected inertia to the drive system. Structural resonances were kept to a low value by using a box type weldment structure to support the elevation axis. This structure was made of ⅛" thick cold rolled steel per Mil Spec. QQS-636. Three stiffeners were placed longitudinally for additional strength. To protect the weldment against the elements the entire assembly was hot dip galvanized and then painted. The resonant frequency of this member was calculated to be 8 cps. The azimuth base and elevation head, made of cast steel, offers no resonance problems.

To reduce the effects of inertia and wind torques the antenna was mounted on the pedestal so that its center of gravity was coincident with the intersection of the azimuth and elevation axes. Design of the elevation support incorporated a scimitar yoke so as to place the antenna center of gravity at the intersection of the pedestal axes. This design eliminates the need for counter weights or wind wings. The entire structure now has a minimum amount of inertia and wind torques.

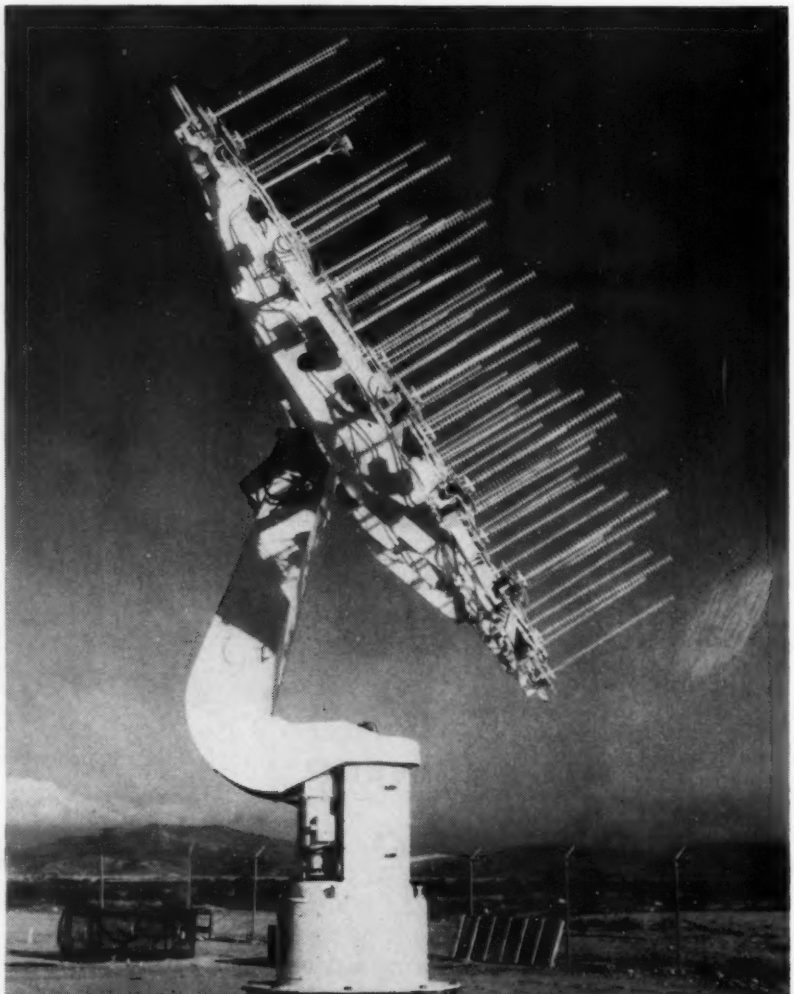

Fig 1 TEMEC Pedestal with typical end fire array antenna. No counter weights or wind wings required. One h.p. motors used in both azimuth and elevation..

LIMIT STOPS

Another important feature of the antenna mount is the use of hydro-mechanical limit stops. To protect the antenna and pedestal from shock loads in the advent of an electrical limit stop failure, it was decided to use hydraulic pistons in place of spring or hydraulic bumpers normally used. The hydraulic bumper type of stop gives little shock protection to the system for velocities below the critical velocity for which it was designed. The spring type of stop is unsatisfactory because of the extremely long spring required to protect the antenna adequately.

The hydraulic stops, designed by Temec, Inc., consist of two hydraulic cylinders, one attached between each cantilever arm of the antenna support casting and a pivot point on the corresponding side of the elevation extension weldment. Construction of the hydraulic stop is such that a buffing action is introduced within the last 5° of travel of the piston on the extended stroke. The amount of buffing action required, dependent on mass and velocity of the antenna, is controlled by adjusting a check valve which in turn regulates the flow of hydraulic fluid through a return line from a buffing chamber on the extended stroke end of the cylinder. Thus, regardless of the antenna velocity, from 0° to 72°/sec, the stops bring the antenna smoothly to rest without exerting shock torques on the antenna or pedestal.

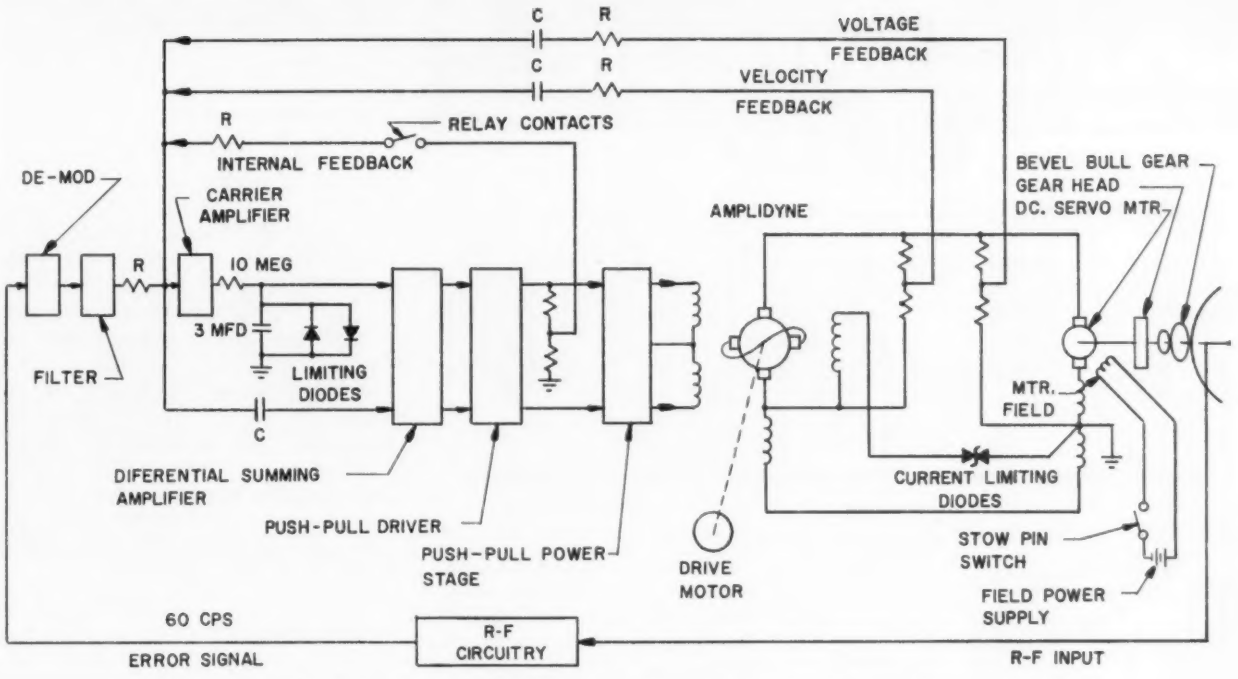

Fig 2 Functional block diagram of elevation servo control system.

CONTROL OF BACKLASH IN POWER GEAR TRAIN

Backlash in gear trains has always plagued the servo designer because of the resultant reduction in phase margin and dynamic accuracy. Although spring loaded power gears have been used to eliminate backlash, attendant increase in friction and decrease in gearing efficiency offset the advantages to be gained from such a device. The backlash problem was solved by using a gearhead fastened directly to the dc servo motor. The output shaft of the motor was coupled to the gearhead with an Oldham coupling. Backlash through this gearhead was kept below 1.5 milliradians.

To control the final gear mesh between the gearhead output pinion and the bull gear in azimuth, the motor-gearhead assembly was mounted with a slotted mounting hole pattern which was offset from the center line of the output pinion shaft. Thus, by rotating the entire motor-gearhead assembly the backlash could be adjusted in the final gear mesh. With this arrangement the backlash could be controlled but, under field operation, it was found that the gearhead would work loose in the adjustment slots. To remedy this situation, flat steel slugs were inserted in the adjustment slots after the final backlash adjustment.

The bull gear in elevation consists of a bevel gear mounted on the elevation axis. The gearhead output pinion is a bevel gear which meshes with the bull gear. Backlash, with this type of gearing, could not be controlled as it was in azimuth, which used straight spur gears. In this case, the final mesh is controlled by positioning the elevation shaft to which the elevation bevel gear is attached, using the bearing retaining nuts on either end of the shaft.

The gear head consists of a double planetary gear train with a ratio of 220:1. It has a power rating of 1.0 H.P. Both the motor and gearhead are totally enclosed and need no special treatment to protect them from the environment.

DATA GEARS

A data package is provided on each axis. This package houses three synchros, a torque transmitter, a control transmitter and a control transformer, all connected through a 1:1 gear ratio to the respective axis. The limit switches and cams are also located within the data package. A separate data gear is provided in each axis to drive the synchros and limit switch assemblies. All synchro gears are of the spring-loaded, anti-backlash type.

With spring-loaded gears on the individual synchros a problem arose as to how the synchros could be replaced without the spring-loaded gears unwinding. This difficulty was overcome by first rotating the two halves of the gear so that the spring was loaded by 5-tooth widths. The half-gears were then pinned in such a way that a movement of one-half of a tooth width was allowed. This allows the gear to be installed in a "blind" hole and the teeth on the mating gear will force the spring-loaded gear open the one-half tooth free movement provided.

STOW PINS

The conventional method of fastening mechanical stowing pins is to place them on the periphery of the casting located on the axis to be stowed. This method would have been satisfactory in azimuth but not in elevation. The elevation casting has such a small radius that the shear forces on the stowing mechanism would have been prohibitive. The alternative method of mechanically locking the power gears was impossible because of the sealed gear head.

Final solution to this problem not only provided mechanical stowing, but also a means of manually moving the antenna. The motors were disassembled and a spline was fastened to the end of the armatures. A handwheel assembly was then fastened to the motor end bell. This assembly has an internal spline shaft fastened to the handwheel, which is free to move in or out of the assembly.

Detents are provided to hold the handwheel in any of the three positions. With the handwheel all the way out the pedestal is free to be servo controlled. In the middle position a microswitch electrically disconnects the field of the motor and the spline coupling is engaged. The pedestal can then be moved by rotating the handwheel. With the handwheel all the way in, a key on the handwheel engages a slot on the housing locking the motor shaft and preventing the antenna from moving.

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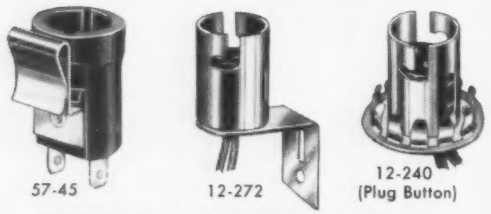

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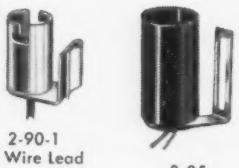

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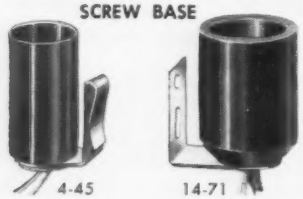

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HANDWHEEL ASSEMBLIES

When the equipment is in manual operation a human operator becomes part of the servo loop. If he wishes the antenna to follow a moving target, or if he wishes to merely position the pedestal to a desired location, he visually detects the existing error. Since the human operator has a much faster speed of response than the servo, a method must be devised to smooth the inputs into the servo from the operator. To provide this smoothing, an inertia wheel and a friction adjustment were used on the handwheel assembly. The final inertia and friction were determined experimentally and resulted in smooth manual operation.

DRIVE SYSTEM

The servo drive system allows the antenna to be positioned manually or to track an airborne vehicle automatically. In essence, the control system consists of a dc chopper stabilized amplifier which drives an amplidyne, which in turn controls the drive motor. The servo is a Type II that has a velocity constant of infinity. The accompanying functional block diagram shows the elevation servo control system.

The chopper stabilized amplifier is conventional with the exception that it uses the amplidyne as an output stage. DC gain of the amplifier – amplidyne combination is over 1 million. Frequency response of the amplifier is controlled by voltage feedback, which is differentiated in order not to reduce the high dc gain capabilities of the system. One advantage of using a high gain dc amplifier to drive the amplidyne is that no field adjustments are required once the stabilizing networks have been set at the factory. In previous systems an anti-hunt control was incorporated in the servo system which allowed the stability of the system to be varied. It was felt that this type of adjustment is unsuitable since not only the stability but also the dynamic accuracy is affected by such a control. By eliminating servo adjustments the dynamic accuracy of the servo is maintained.

Since the amplidyne constitutes the output stage of the dc amplier no voltage feedback is obtained when the amplidyne is not running. When the system was still in the developmental stage, it was found that excessive voltage transients occurred when the amplidyne was first started. It was found that the amplifier was in full saturation due to residual noise and high gain. Thus,

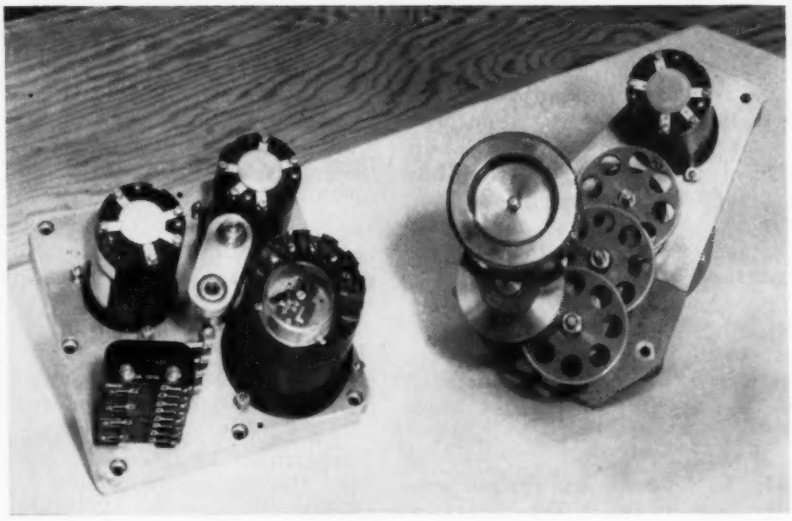

Fig 3 Data package and handwheel assembly used in the scimitar yoke pedestal system manufactured by Temec Inc., Van Nuys, Calif.

when the amplidyne was started it delivered full voltage to the motor which in turn moved the pedestal. Violent oscillations resulted until the feedback voltage pulled the amplifier out of saturation. To eliminate this difficulty an auxiliary voltage feedback path was utilized to hold the amplifier out of saturation when the amplidyne was not running. The required feedback voltage was derived from a resistive voltage divider network placed on the plate of one of the push-pull driver stages of the amplifier. This voltage was then fed back to the amplifier's input through a set of relay contacts. The power switch that starts the amplidyne also controls this relay. When the amplidyne is off, the internal voltage feedback holds the amplifier out of saturation. When the amplidyne is turned on, the internal voltage feedback is automatically disconnected and the over-all feedback networks control the system. This method of turning the system on eliminated the transients and allowed the servo to be put into operation smoothly.

A velocity bridge is used to derive the rate feedback necessary to stabilize the servo positional loop. Rate feedback is differentiated so as to eliminate any servo errors due to following constant velocity inputs. This technique results in a Type II servo which reduces the velocity error to zero.

A major difficulty which exists when using a chopper stabilized amplifier is the extremely long recovery time when a transient enters the system. In the present amplifier the carrier amplifier output filter has a time-constant of 30 seconds. If a voltage transient occurs that has a value higher than that required to saturate the output stage, the system operates as an open-loop system. This is so because a change in the amplifier input is not reflected at the output since it is in saturation. Furthermore, the output is kept in saturation since the 30 second filter has not discharged. The resulting effect on the over-all servo system is that when a large step input is introduced, the servo has a very large overshoot, which often exceeds the value of the original input displacement. Relays could have been used to discharge the 30 second filter network, but it was felt that this method would reduce overall reliability.

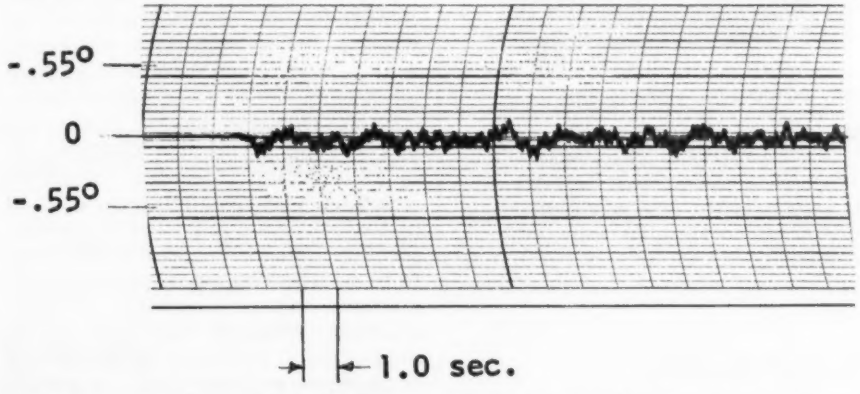

Fig 4 Actual recording made of the servo error in azimuth with an input velocity of 72°/sec. The calibration is 0.055 degrees/ chart line; chart speed is 5 mm./sec.

A compromise was reached by using two silicone diodes in inverse parallel across the filter capacitor. This limited the maximum capacitor voltage to approximately plus or minus 0.5 volts. The diode network reduced the overshoot for saturating input steps to practical values. It also reduced the settling time for large step inputs to 1.5 sec, which is about 1/10 the time when the diode network was not used.

General characteristics of the entire servo control system are smooth operation from 0 to 72°/sec and low dynamic error.

CURRENT LIMITING

Since the drive system is capable of speeds up to 72°/sec, excessive currents flowing in the armature circuit when a sudden motor reversal takes place would tend to cause loading in the amplidyne and ring-fire in the motor. To protect the equipment against excessive current transients a current limiting network is employed in the amplidyne itself. This network consists of a double anode zener placed in series with the extra amplidyne field windings. This combination is then placed across the motor compensating windings. Voltage across the network is thus a function of the current flowing through the compensating windings. When the current reaches a certain value the voltage drop across the compensating winding is sufficient to break down the double anode zener. When the zener diode breaks down current flows through the amplidyne auxiliary windings in such a direction as to create a flux which opposes the main field flux, thus limiting the amplidyne output. Since current limiting is done entirely within the amplidyne, an electronic circuit failure cannot cause excessive currents to flow in the system.

Since torque output is directly proportional to motor armature current, the current limiting network also limits the available output torque. If the motor load is primarily inertial, the output acceleration is also limited. The acceleration of the present system was measured and found to exceed 50°/sec^2 for both azimuth and elevation. This acceleration figure could be increased but not at the expense of motor and amplidyne life.

Evaluation tests are still being performed on the system. In one test, an error of 0.07° rms was measured at a rate of 72°/sec. This error was caused by bearing and gear irregularities. The system is presently being installed at Edwards Air Force Base for tracking planes flying at mach-2 and also by the P.M.R. ships for missile telemetry reception.

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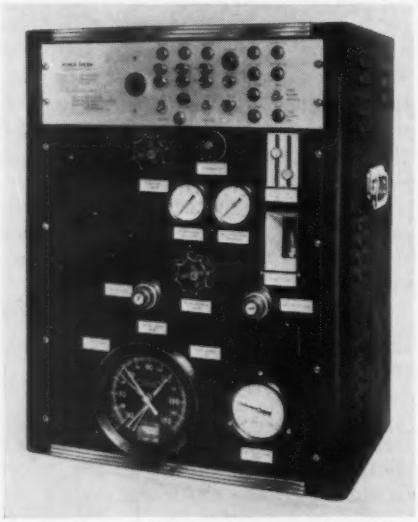

TEMPERATURE CONTROL

Controlled Water Supply Heats or Cools Equipment to Maintain Constant Temperature

Controlled temperature water supplies for maintaining operating temperatures of critical equipment have heretofore been homemade, inaccurate plumbing jobs, or large immobile units. A completely self-contained, portable water supply that maintains operating temperature of equipment to ±1°F is now available in one package approximately 5.5 cubic feet in volume. The unit, called Powertherm and manufactured by Astro Dynamics, Inc. of Burlington, Mass., supplies or removes heat up to 1 Kw, or provides cooling up to 1½ Kw. Astro Dynamic engineers have packaged the complete system – pump, storage tank, refrigeration and heating units, alarms, indicators and controls within a standard radio relay rack 28″ by 22″ by 15″.

Both the flow rate and the temperature of the water delivered to the equipment are adjustable over a wide range. Capacity of the centrifugal pump is 2.7 gpm at 55 psi pressure and the flow is monitored by a flowmeter with a range of 0.2 to 4 gpm and dual pressure gauges, 0 to 60 psi, for inlet and outlet pressures. Cooling is accomplished with a completely sealed ½ HP refrigeration system rated at 5000 BTU/hr at 90°F ambient and a suction temperature of 25°F. Heat is supplied by a 1000 watt heater. An adjustable thermostat, with a sensitivity of ±0.1°F and an operating differential of ±1°F max controls the heating and cooling. The inlet temperature gauge has a range from 40 to 140°F; the outlet temperature gauge a range of 30 to 150°F, with high and low alarms.

Because the water system is a closed one, self-sealing quick-connectors are used. A stainless steel tank, designed for 60 psi, has a capacity of 2 gallons. Fully complemented by relief, drain, and bypass valves, the system also includes a sight-glass tank level, with low water level float switch which provides alarm and breaks circuit to the heater.

The controls and audio-visual alarm system have been designed to provide not only fail-safe operation, but also flexibility and ease of maintenance. Temperature alarms may be bypassed when the Powertherm is used for fast warmup of equipment. When the demands of the operating equipment require intermittent excesses, time delay relays are locked in; as the load returns to normal within a safe time, the Powertherm can resume operation without attendance. Alarm lights remain lighted showing evidence as to the excesses occurring during operation. Convenient electronic-operating-equipment interlock is afforded through a front panel receptacle; should the Powertherm alarm system go off, the electronic equipment would be instantly shut off. Plug-in, modular construction is used to insure minimum down-time.

Originally, Powertherm was developed to maintain operating temperature of missile-guidance controls in the hangar (as part of the ground support equipment) and in the laboratory. Its capacity, however, suggests use with communications and radar equipment, control equipment, medical equipment, and process machinery. • • •

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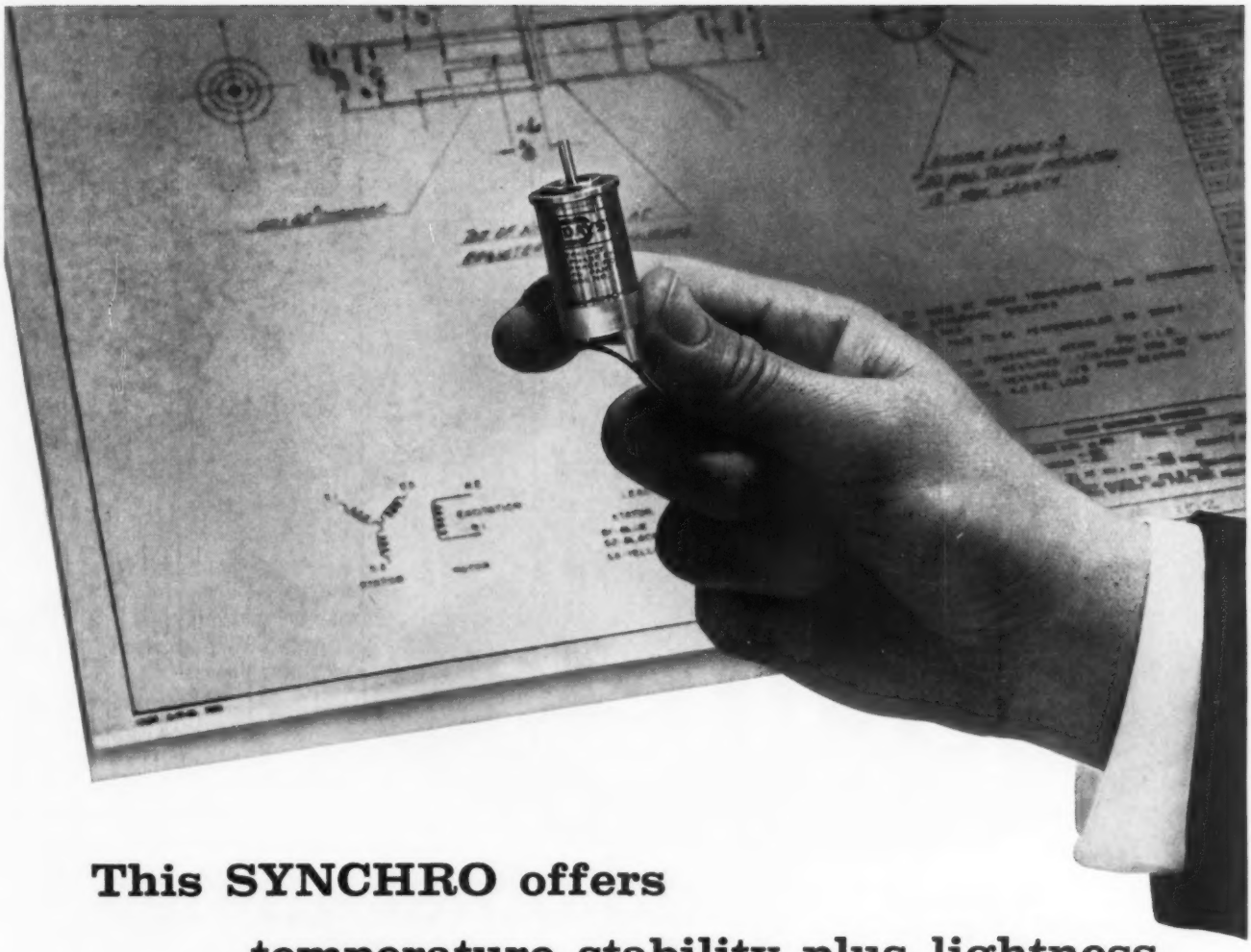

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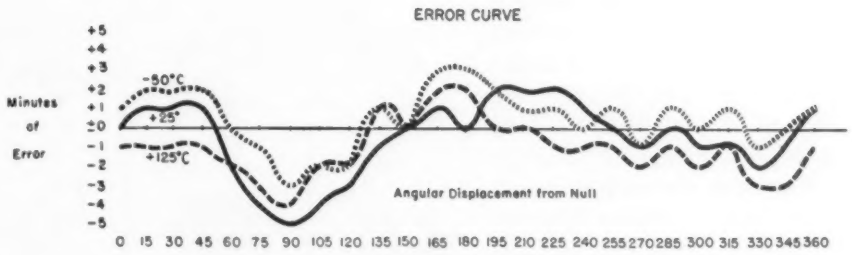

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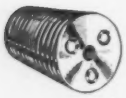

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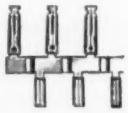

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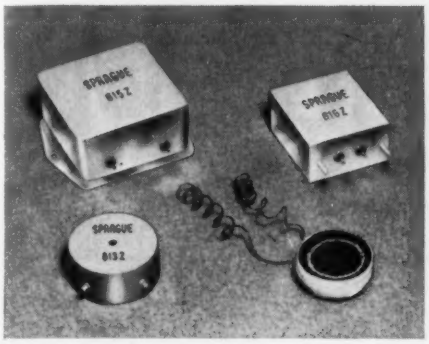

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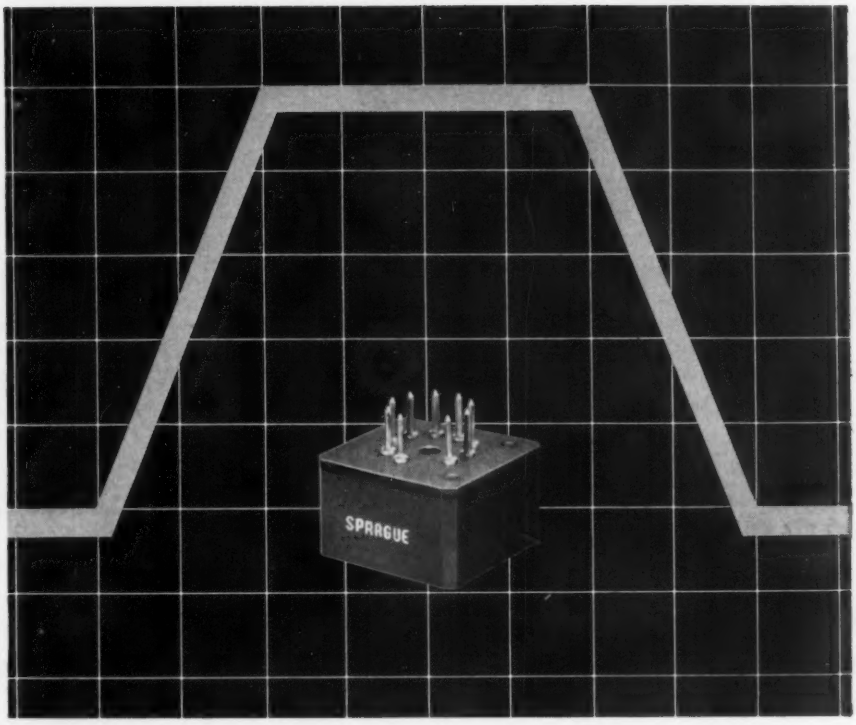

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With these ideas in mind and recognizing that electronic equipment will be composed, more and more, of basic functions, R. C. Swengel and W. R. Evans of AMP, Inc., Harrisburg, Pa., have developed a new mechanical approach to the construction of modular electronic equipment. In a paper presented at the recent ASME Aviation Conference, Swengel & Evans described their technique as a universal packaging system that provides a practical way of integrating all types of electronic modules in specific equipment.

INCREMENTAL MODULES

Based on an incremental form rather than a fixed size module, the new modular structure begins with a rectanglar prism form which can be expanded or contracted in equal increments on any of three major axes. Fig 1 shows the basic form and Fig 2 shows actual examples of various length and width combinations having a specific height in the 0.100-in-grid modular system and another in the 0.200-in. system.

Slots, shown in the figures as part of the module form, accommodate and protect resilient spring contacts. Fig 3 shows the contacts located in the module slots and in front of the module ar eshown progressive steps in the engagement of the resilient spring contact with a flat metal rib. This rib, which is the rugged and nonstressed half of the contact pair, is a part of the permanent interconnecting system. The module contact consists of two independent spring systems, each having two contacts, thus increasing the reliability factor by employing four parallel contacts.

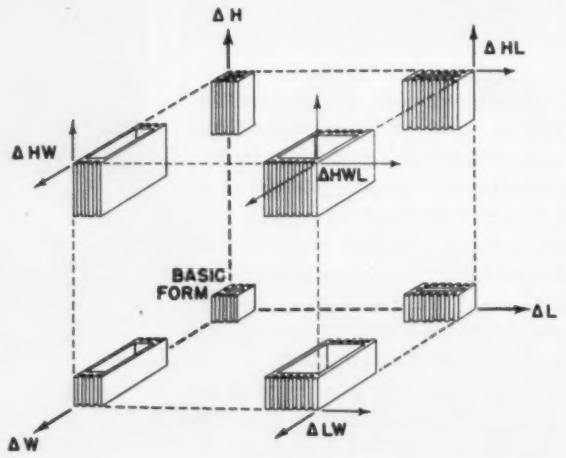

Fig 1 Incremental modules. Slots on opposing sides depict the relative number of input-output connections. H, L, and W illustrate incremental dimensional change in height, length, and width, respectively. Combinations of incremental change in H, L, and W, appear as HL, LW, and HW. The final HWL represents simultaneous incremental change on all three major axes. Thus, the basic form lends itself to many physically diverse approaches in the design and construction of electronic functions. This extreme flexibility also makes possible the consideration of plug-in modules that are basic enough to be economically expendable. The reason for this is that neither the module nor the interconnecting means are fixed in physical size. With this basic but variable form, it never becomes necessary to establish a fixed size for a module, for this often necessitates the inclusion of more components or electronic functions than would constitute an economically expendable module, and a corresponding waste of valuable packaging space.

SERIES CIRCUITS

Fig 4 illustrates the manner in which the basic modules are adapted to a pure series circuit. Intermodule series connectors are mounted in an upright position on a base chassis. The modules are plugged between the series connector uprights and the connectors act as shorting bars between adjacent modules from one end of the assembly to the other. Inputs and outputs are connected by point wiring to extensions of the series connectors projecting below the chassis. Feedbacks can also be connected in this manner, although such circuits can also be carried through the modules themselves.

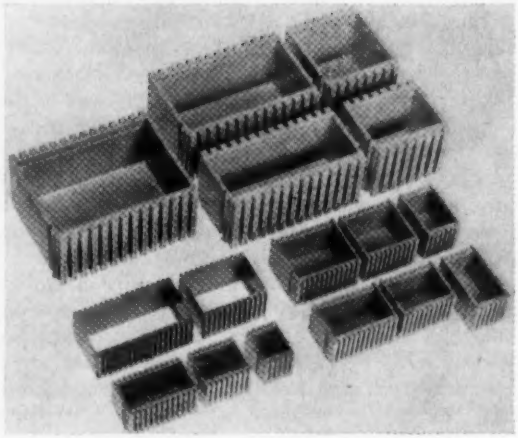

Fig 2 Examples of incremental modules.

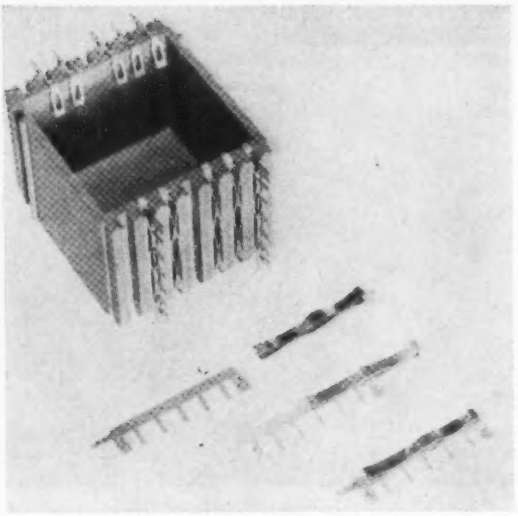

Fig 3 Circuit contact mechanism.

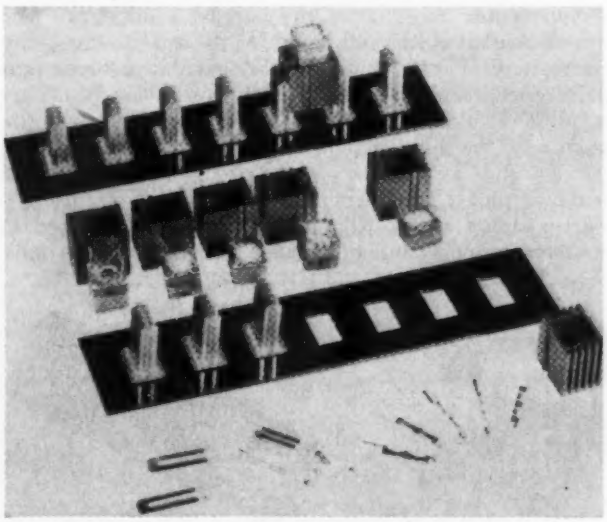

Fig 4 Series construction using incremental modules.

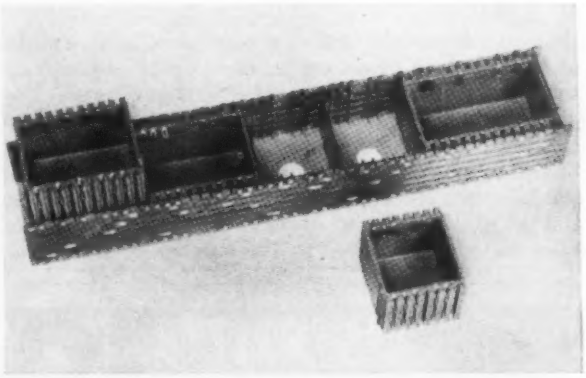

Fig 5 Parallel circuit construction using incremental modules.

PARALLEL CIRCUITS

When the basic modules are integrated in parallel circuits, illustrated in Fig 5, the module contacts face the parallel circuits on both sides of the module assembly. The rib contacts, integral parts of the parallel circuits, act as conductors from the module contacts to any of the horizontal conductors on the parallel circuits. The horizontal conductors are the parallel circuits and feedback paths from any module to any other module. The rib contacts plus the parallel circuit boards constitute the equivalent of a double clad plated-through-hole printed circuit board on both sides of the module assembly. Figs 6 and 7 show two methods of applying the same basic modules to more complex circuitry involving multiple module subassemblies in various combinations of series and parallel circuits.

FABRICATION TECHNIQUES

Standard module forms are compression molded, using glass-filled diallyl phthalate, although any material that can be machined, cast or molded can be used. Slots are molded integrally with the modules to receive the resilient module

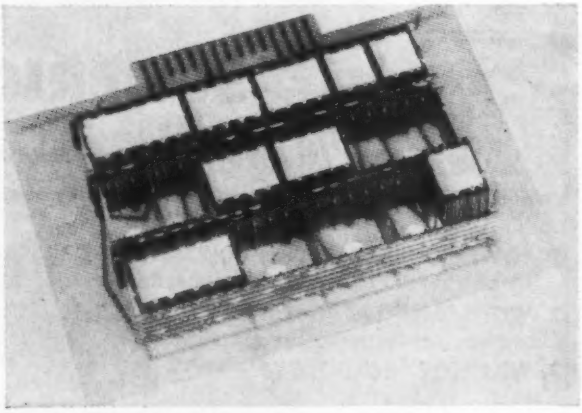

Fig 6 Parallel-series circuit construction. Three modular assemblies of parallel circuit construction are mounted on a base-printed board. In this arrangement, the inter-module parallel connections on one assembly are still made through the rib contacts and the horizontal conductors of the parallel circuits. Interassembly connections, as well as inputs and outputs, are made through the base-board circuit and may be either series or parallel.

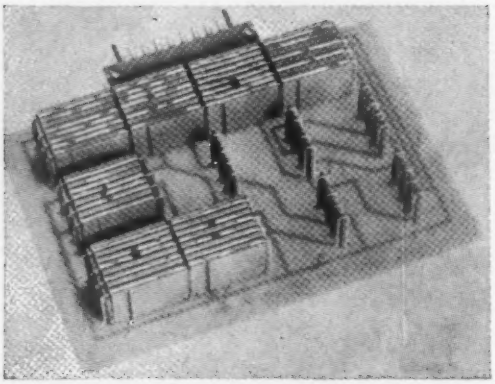

Fig 7. Parallel-series circuits using series construction. Three module assemblies are mounted on a base-board circuit. Series connectors make contact with the base-board circuitry by soldering. It is probable that the base circuits will be used for parallel interconnections.

contacts. Materials used for parallel circuits can be any of the standard single copper-clad circuit board materials, such as XXXP Phenolic or G-10 glass epoxy. For any particular height and grid desired, the boards are preslit to width. A mechanical process is used to remove a portion of the copper cladding leaving only conductor paths. The slots are then cut in the top and bottom edges of the boards.

The parallel circuit contact is stamped with multiple tines on one side equal to the number of horizontal conductors on the parallel circuit. For assembly, it is necessary for a rib tine to mate with a predrilled hole in the desired parallel conductor at the proper location. All other tines are removed except the upper and lower tabs which insert into the top and bottom slots of the board. The tabs are clinched to fasten mechanically the rib to the circuit board. The rib tine extending through the drilled hole in the circuit board is clinched prior to soldering.

If the contact must be made either from the module or from any of the parallel conductors to the base-board circuit, then the tine on the bottom of the rib contact is left intact. Otherwise the bottom tine is removed.

The two parallel circuits are mechanically assembled by using the spacers as rigidizing members. The spacer tabs are similar to the rib tabs and are clinched onto the boards. All electrical connections on the parallel circuits are made simultaneously by solder dipping. The spacers, using their base tabs, are finally clinched and soldered to the base board to fasten the assembly mechanically to the base-circuit structure.

Present concept is based on a 0.200 or 0.100-in-grid system. For instance, if the specific system chosen is the 0.100-in. grid, the module contacts are on 0.100-in. center lines; the tines on the parallel circuit contacts are on 0.100-in center lines as are the parallel conductors. The nominal height, width, and length of the modules can vary in increments of 0.100 in., and after assembly the base tabs on the spacers and ribs which attach to the base board are spaced in increments of 0.100 in. Therefore, the entire system is on the same incremental grid in three dimensions.

Design and layout of a parallel-circuit assembly can be greatly simplified and carried out very quickly by using a program circuit chart. All of the information required to manufacture one complete parallel assembly can be indi-

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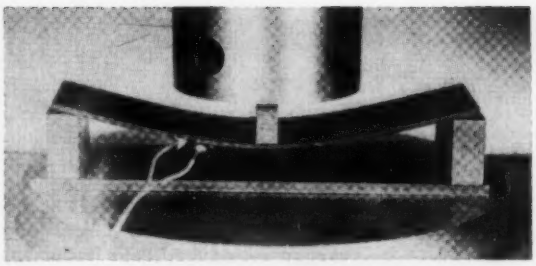

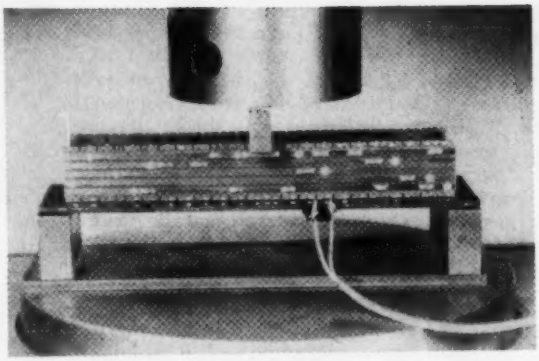

Fig 8 Top shows 4½-in. length of 1/16-in-thick single copper clad XXXP circuit board used as a simple beam with a 10-lb. concentrated load. Bottom shows a 4½-in. length of a parallel three-dimensional structure loaded in identical fashion. Applying a 0.7-lb load stresses the copper cladding on top flat-plate construction to the yield point whereas a 16-lb load must be applied to the three-dimensional structure before this yield point is equalled.

cated on one program circuit chart, including the two necessary parallel circuit boards, circuit contacts, spacers, module contacts, and module shells. Information from the program circuit chart is transferred to cards.

Standard circuit-board material, stocked in semi-finished form and ready for programming, plus a reel of rib-type circuit contacts (with all tines in place) are fed into an automatic programming and assembly machine. In accordance with the information stored on the card, required holes are drilled in the board and required circuit breaks are spot-faced into the copper conductors. The contact tines are automatically programmed in sequence by removing all tines excepting those required to complete a circuit. The machine inserts the contacts and clinches them onto the board. A completely programmed and assembled parallel circuit is the end result. Using this process, one prototype can be made as easily as a large production run.

Through the use of this new packaging technique, present-day electronic functions, or those proposed for the future, are easily adapted to simple or complex circuitry. For simple series circuits, no circuit boards are required whatsoever. For parallel circuit applications, very little, if any, drafting or board layout is required and a special circuit construction can be designed and produced in minimum time. Short-run or prototype parallel circuits can be produced with standard pantograph equipment. Therefore, automatic production equipment is not necessary for a trial run. The plug-in module allows for quick testing of each function, not only in application, but during production assembly. The structural design incorporates redundant, reliable contacts. Fig 8 illustrates the superior performance that can be obtained with the three-dimensional mechanical design as compared to an essentially two-dimensional structure.

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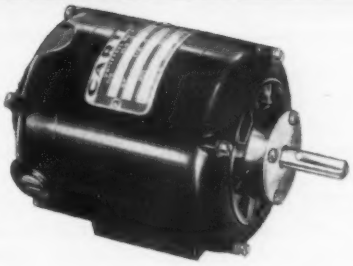

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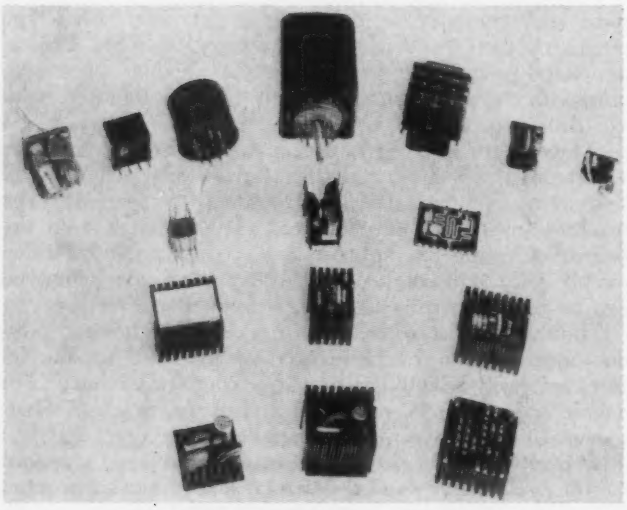

Fig 9 Module-component adaptability. Individual components can be preconnected, inserted in the module and soldered or welded to the tabs on the contacts. The standard module shell is molded with a bottom which allows it to act as its own encapsulating mold. Where repairability of the individual components of a modular function is required, the bottom of the module shell can be left open for accessibility. The same group of components can be hermetically sealed before insertion into the module shell. Only the output and input leads need protrude for connection to the module contacts. Welded stick assembly, enclosed by two of the shells, is an example of this construction. The integrated circuit construction provides for structural strength and resistance to shock, vibration, and other applied stresses because each part serves many purposes. The module plugs into the circuit instead of onto the circuit. The circuit serves as a mechanical structure as well as means for interconnection. The module shell encases and protects the electronic functions, contains and protects the contacts and is, in itself, a high-strength almost indestructible unit.

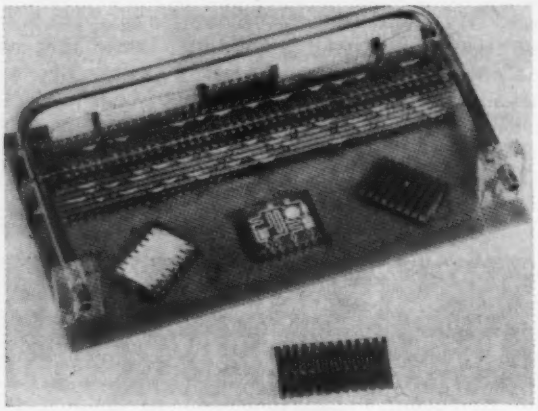

Fig 10 Thin film wafer assembly. Tabs can be placed on both the top and bottom of the module contact to connect with the wafer at the top, bottom, or both. Individual wafer modules can still grow in height or length providing variable interconnections as required. Each individual wafer assembly can still be easily removed for maintenance. By placing two rows of wafers back to back, the standard type programmed parallel circuits can be used. One possible method of cooling a double section of wafers is to insert a cooling fin between the two wafer rows. The fin is welded or brazed to a cooling tube or other intermediate heat conductor if desired.

COST FACTOR

While the electrical and mechanical advantages of this new approach in packaging are very worth while, the cost factor is equally important. The total costs of incorporating this new system may exceed the cost of standard solder-dipped circuit-board systems as now used, or the cost may be less where the electrical design and interconnections of subsequent equipment vary because of differing applications. But Swengel and Evans contend that where plug-in maintainability is desired, their approach should be less expensive because this construction eliminates the usual male-female connectors and provides means of interconnection without additional parts. The authors also believe that the industry now generally recognizes that the original cost of more complicated electronic equipment is relatively unimportant as contrasted with maintenance expenses — the ratio often being in the order of one to ten. Their system embodies the philosophy that the plug-in module can be reduced to a point where it can be economically advantageous to throw it away at time of failure.

AREAS OF ADAPTABILITY

Fig 9 illustrates the adaptability of the basic module shells to various types of electronic components and functions. Since the basic module form is a hollow rectangular prism, it can be made to contain any modular electronic function of like form, however fabricated or constructed. Even modular electronic functions with forms more closely approaching a two-dimensional rather than a three-dimensional continuum can be accommodated by this new system.

Thin film or wafer functions as illustrated in Fig 10 can be adapted by molding a flat module form with contacts on one side only. The procedure used for wafers can also be utilized with any of the new solid-state, molecular functions. Where micro-miniaturization of these functions has been accomplished, several can be interconnected and used as a larger multifunction module which provides a size more compatible with this mechanical structure.

The modular system described here is in an advanced state of development and initial stage of production at AMP, Inc., under the trade name of "AMP-MECA" (Maintainable Electronic Component Assembly). Numerous prototype equipment is under evaluation. A complete test program is nearing completion, and includes tests covering extreme electrical, mechanical and environmental requirements. Initial test information substantiates the practicability of the design in all respects. Initial production stages indicate that the system can be produced by economical and automatic methods as described. Prototypes have proved the feasibility of adapting the new technique to diversified applications.

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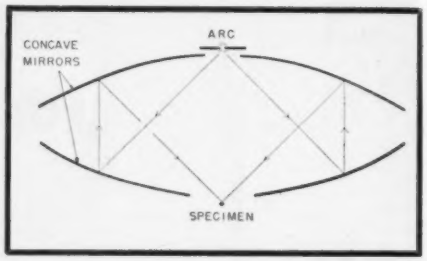

ARC IMAGING FURNACE

Contamination of Specimen Eliminated in New Design

Although furnaces using optically concentrated arc radiation have been commercially available since 1957, the design of a "clam shell" furnace represents a major improvement in efficiency. Utilizing an idea conceived by George Ploetz, chief of the pyrogenic section of the Air Force-Cambridge Research Lab., engineers at Arthur D. Little, Inc., Cambridge, Mass. designed and developed a furnace in which two opposing concave mirrors capture radiant energy from an electric arc and focus it into an area one-half inch in diameter to create temperatures in excess of 3500° K (6700° F.)

Location of the radiant energy source and the specimen outside the reflecting system substantially reduces shadowing losses. Radiation enters the "clam shell" reflecting chamber through a circular opening in the back of one of the mirrors and converges on a specimen outside an opening in the back of the second mirror.

In addition to crystal growing and materials research, the furnaces can be used in refining, in chemical processing, and in welding materials in any desirable atmosphere (or vacuum) free from contamination.

"Clam shell" furnaces could also be used in conjunction with radiant energy sources other than arcs with optical systems designed to accomplish specific tasks. Radiant energy from these new furnaces could also be incorporated into machines or production systems requiring intense heat continuously. Two "clam shell" systems could also be used jointly to heat work pieces from both sides.

Primary advantages of these imaging furnaces is that by optically concentrating radiant energy at a distance away from the burning arc, contamination of specimens is eliminated and better control over temperature is provided.

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It provides electrical responses proportional to either stress or strain, at the discretion of the user, by means of two independent axial strain-sensing elements oriented 90 degrees apart. One element measures the conventional strain. The other element acts as the automatic computer by rejecting the axial component of strain caused by stress in a transverse direction. The combined elements then respond only to that component of strain produced by stress in the axial direction.

The two sensing elements have a common electrical connection to permit independent use for measuring conventional axial or transverse strains, or combined use to measure stress along the principle gage axis.

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- Stress – along principal sensing axis.
- Strain – along transverse axis.

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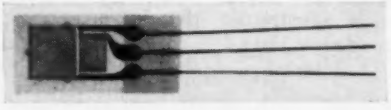

Fig 1 Built-in computer automatically solves strain-to-stress equations in this tiny bonded resistance-foil SR-4 gage developed by Electronics & Instrumentation Div. of B-L-H. The gage is approximately 1/4" wide by 9/16" long. Two sensing elements, oriented 90 degrees apart, permit measuring stress along the principal axis, strains in both axial and transverse directions.

Gages are available with a phenolic base construction, Constantan foil and with resistance ratios and temperature compensation for mild steels, stainless steel and aluminum. They can be bonded easily with such room-temperature curing cements as BLH EPY-150 epoxy, Eastman 910 cyanoacrylate for applications up to 150 degrees F, or BLH EPY-400 epoxy for elevated-temperature applications up to 450 degrees F. Baldwin-Lima-Hamilton Corp., Phila., Pa.

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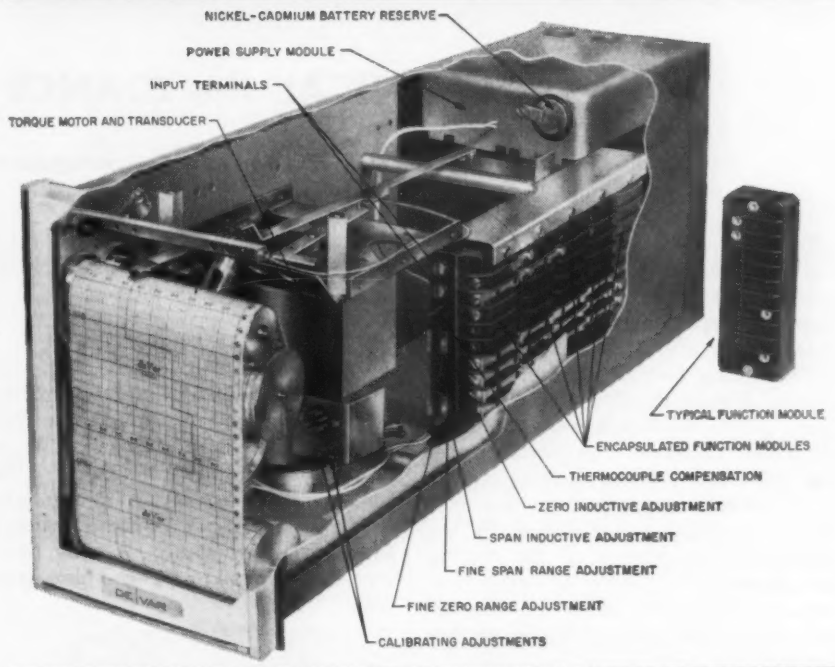

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TESTING

MECHANICAL IMPEDANCE TESTING

Impedance Head Measures Forces and Accelerations at the Same Point

Laboratory vibration testing of an object often assumes that the vibration environment is defined when the spectrum of displacement or acceleration versus frequency of the environment at the mounting location of the object is known. Wilson Bradley, Jr. of Endevco Corp. points out that this assumption is not often justified. The object under test influences its own environment in a way that is dependent on the ratio of its mechanical impedance to the mechanical impedance of the driving or mounting structure at each frequency. Examples show extreme effects when mechanical impedances are ignored.

Mechanical impedance data must then be known for the driving structure and in some cases the object under test. Impedances of structures are readily measurable with small portable shakers and impedance measuring gages or equivalent that provide accurate force, acceleration, and phase measurement at each frequency of interest.

MECHANICAL IMPEDANCE

To set up a sinusoidal vibratory motion at a given point in a mass, a sinusoidal force of the same frequency is required. *Mechanical impedance* is the force required to impart to the point a unit of velocity at a given frequency. Mechanical impedance, Z, may therefore be expressed as a complex quantity:

$$Z = F_o/\bar{\dot{x}} = F_o/j\omega\bar{x}$$

where F_o is the applied force,
$\bar{x}$ is the vector representation of the displacement in the complex plane, and $\bar{\dot{x}} = j\omega\bar{x}$ for the given frequency. Thus Z requires for its specification either its real and imaginary parts $(a + jb)$ or its absolute value and phase angle

$$(Ae^{j\phi})$$

The fact that mechanical impedance of almost any object is frequency dependent is illustrated in Fig 1. Curve (a) describes the point impedance of an idealized mass which increases in impedance with increasing frequency. Curve (b) describes an idealized viscous dash pot or damper. Curve (c) describes an idealized spring which decreases in impedance with frequency. The fact that all structures are complex combinations of these three idealized components leads to typical point impedance graphs as shown in Fig 2. It is these wide variations of more than 100 to 1 in impedance values that make it necessary to consider the effect of structural impedances on shock and vibration reliability. Table I is an example illustrating the importance of impedance data.

To determine mechanical impedance experimentally, measurements must be made for each frequency of interest. These measurements must include the motion at the point of application, the magnitude of the sinusoidal driving force at that same point, and the phase relation between the two.

FORCE GENERATION

The vibratory force required for a specific mechanical impedance test has definite upper and lower limits. It must not be so large as to damage the specimen or cause it to operate under nonlinear conditions; but the force must be large enough to produce an accurately measurable motion.

The electrodynamic vibration generator, or shaker, is useful over a wide frequency range – from 5 cps to as high as 10,000 cps. When the shaker is used in a laboratory it is usually mounted to a large mass which absorbs the reaction forces. If it is to be used in the field, where a massive mounting structure is impractical or impossible, a

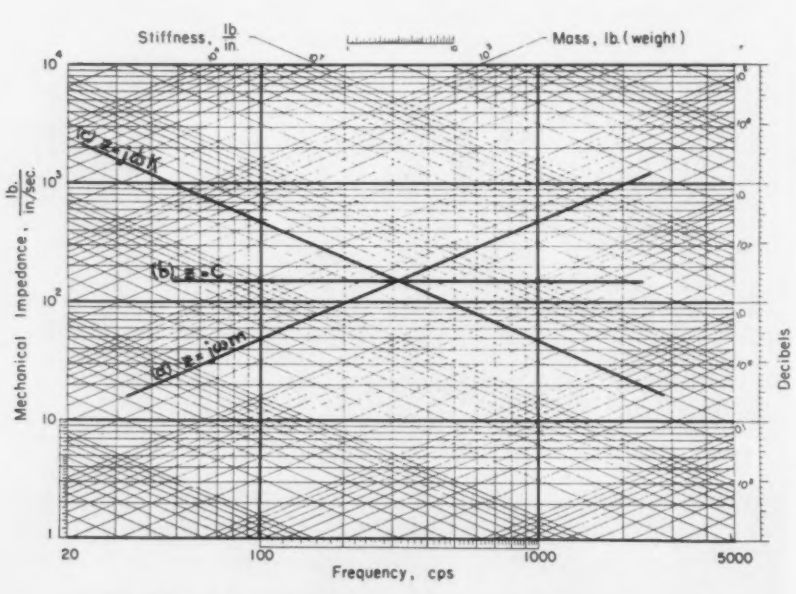

Fig 1 Impedance characteristics of (a) ideal mass, *m*, (b) ideal damper, *c*, and (c) ideal spring of spring constant *k*.

reaction mass is needed. This mass will raise the impedance of the shaker system so that greater testing forces are available. The vibration generator and reaction mass are usually suspended from cables at the desired angle for attaching to the specimen.

FORCE AND MOTION MEASUREMENT

In measuring the driving force, a gage is placed between the vibration generator and the specimen under test, as closely as possible to the specimen. The end of the gage between sensing material and specimen must be stiff enough to transmit the applied force to the specimen without resonance (caused by the mass of the specimen and the spring constant of the end of the gage) occurring over the frequency range of interest.

The velocity of the specimen doesn't have to be measured directly. Impedance may be derived from measurements either of displacement or of acceleration. At low frequencies, velocity and acceleration have very small values, so displacement is the most easily measured. Many displacement transducers are capable of operating above several hundred cps, but the displacement values become so small that velocity or acceleration measurements are more accurate.

Over a middle frequency range, velocity may be measured directly with a "velocity pickup." Accurate measurement by a velocity pickup is limited to an upper range of about 1000 cps.

Crystal type accelerometers measure motion effectively over the frequency range of 20 cps to 10,000 cps. Their small size makes it possible to place them in close juxtaposition with the force measuring instrument. At high frequencies it is imperative to measure driving force and resultant acceleration at the same point to avoid large errors introduced by decoupling between two separate points. The crystals type accelerometer has the further advantage of not using damping, and therefore not introducing phase shift.

A convient and accurate method of measuring mechanical impedance is provided by a single instrument, called an impedance head, which contains both the force sensing and motion sensing transducers. This arrangement gives the closest possible approximation of force and acceleration measurements at the same point on a structure, eliminating motion decoupling and phase shift errors, and provides smaller size and simpler mounting than separate instrumentation.

Figure 4 shows such an instrument schematically where both force and acceleration are measured and averaged over the same circle. The mounting

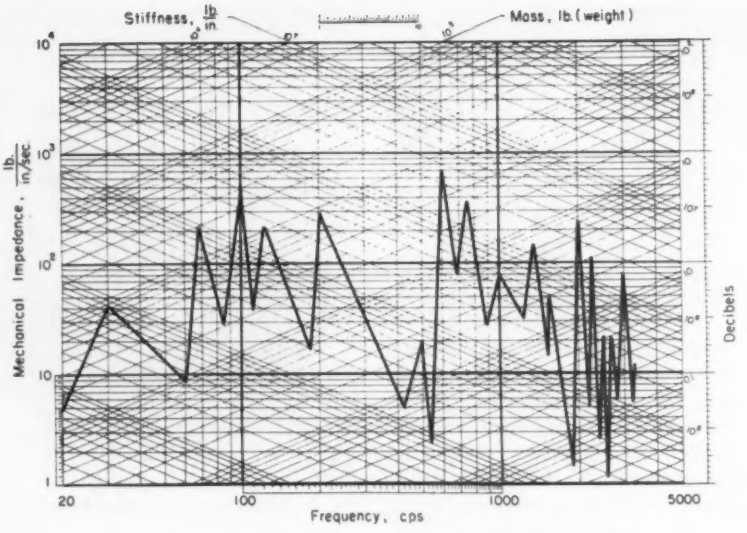

Fig 2 Typical impedance values for a simple structure.

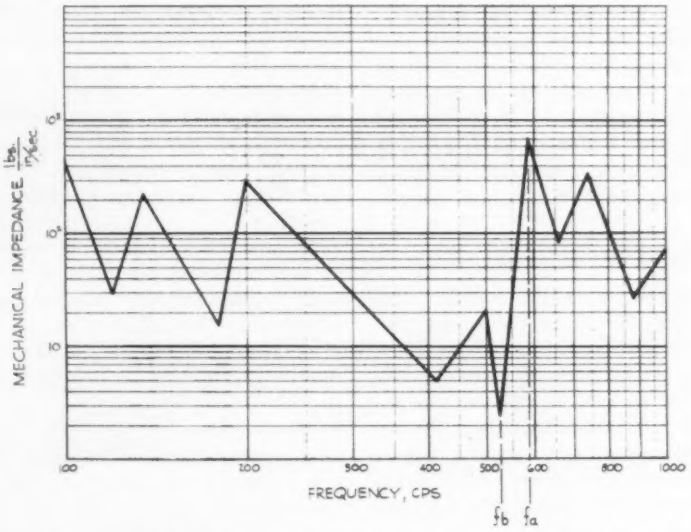

Fig 3 Range of impedance values between two frequencies f_a and f_b.

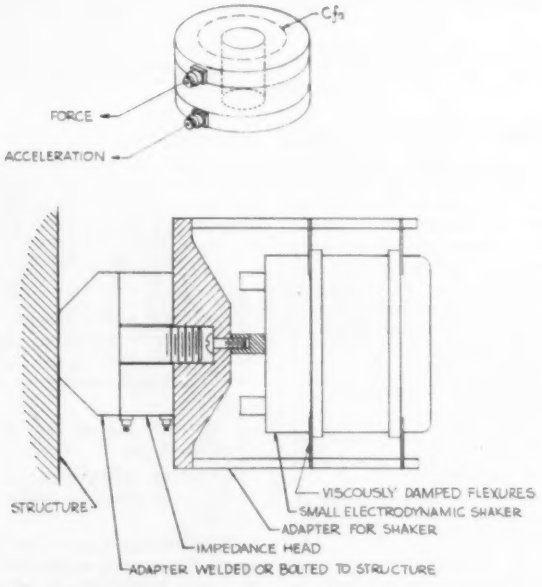

Fig 4 Impedance head and test arrangement.

configuration is also shown with provision for mounting a small electrodynamic vibrator as an integral part of the system or separately suspending a larger force generator. Figure 5 is such an impedance head, manufactured by Endevco Corp. Its sensitivities are in excess of 10 mv per pound of force and 100 mv per "g" of acceleration. The high frequency limit is usually determined by a stiffness line which, for this gage, is approximately 2×10^8 pounds per inch. For medium impedance values the frequency range is therefore in excess of 5000 cps. It is approximately 2" in diameter with clearance for a ½" mounting bolt through the center and is approximately 1" thick. The center bolt mounting with the adapters approaches as nearly as possible the configuration for measuring the true impedance at a *single* point on the specimen, without introducing the distortions of localized impedances caused by multipoint mounts. Figure 6 shows the impedance head with a force generator designed as an integral part of the test system.

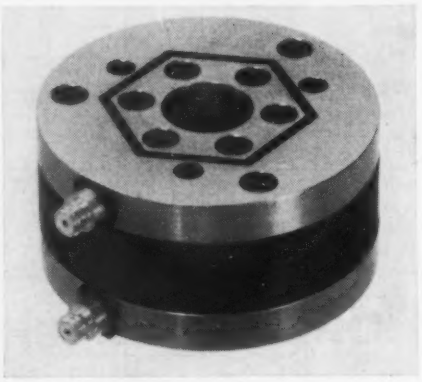

Fig 5 Endevco impedance head.

PHASE MEASUREMENT

Phase angle between the velocity and force vectors should be measured precisely with a phase meter. This measurement must be accurate within $\pm 1°$ when either real or imaginary components of the mechanical impedance are small. It is important to realize that in many instances true phase relationships can be lost unless the following precautions are observed:

- Both transducers must have either zero phase shift or linear phase shift over the frequency range. Transducers free of damping are thus preferable. Damping designed to provide linear phase shift usually does so at only one temperature.
- Both transducers must act effectively at the same point so that impedance of the point is measured rather than the transfer impedance between two points.
- When differentiation or integration to velocity must be made, it is important to preserve the true phase characteristics. This suggests the advantage of a graphical method in which only simple 90° phase corrections are required.
- Many phase meters lose their accuracy when sinusoidal signals containing noise or harmonic distortion are encountered. It may be necessary to select frequencies where simple harmonic motion exists, to use narrow band filtering, or to use special phase meters designed for this purpose.

CALCULATIONS AND PLOTTING

Once the driving force, the resultant motion and the phase angle between them are known with accuracy, the results are calculated and plotted. One of the more useful techniques described by Mr. Bradley is to use the graph paper of Fig 2, shown with a typical mechanical impedance plot. This graphical technique, Bradley says, is of particular advantage when the motion has been measured as a function of displacement or acceleration, because no conversion to velocity is required before plotting.

If displacement has been measured, the results may be plotted from Hooke's Law:

$$K = F/x$$

This means that a measure of the effective spring constant of the system, K_m, can be obtained from the measured driving force divided by the measured displacement at any given frequency. Once the value of the effective spring constant of the system is known for a certain frequency, a point can be plotted on the graph shown in Fig 2, at the intersection of the frequency line and the effective spring constant line. It should be noted that the effective spring constant as measured includes any compliance in the measuring force gage between the sensing material and the actual specimen. For this reason it may be advisable to correct K_m to arrive at the actual value K_s, the effective spring constant of the specimen. Assuming that the measuring gage had a known spring constant of K_e between the sensing material and specimen, then:

$$K_s = K_m \{K_e/(K_e - K_m)\}$$

When velocity has been measured, mechanical impedance may be plotted directly on the graph shown in Fig 2, using the intersection of the mechanical impedance line where $Z = F/\dot{x}$ and the appropriate frequency line. It is interesting to note that while this is the most direct measurement of mechanical impedance, it is the most difficult one to correct for the effective mass and stiffness of the material between the force and motion sensing point and the specimen. The corrections are as follows:

$$Z_s = Z/(1 - AZ_m)$$

where

$$A = 1/[(K_e/j\omega) + j\omega M_e]$$

TABLE I

EXAMPLE ILLUSTRATING THE VALUE OF IMPEDANCE TESTING

Consider the problem of mounting rotating equipment such as turbines, motors, or generators to the structural frame of a building, ship, aircraft, or missile. The rotating device, no matter how accurately balanced, will produce at its mounts a small vibratory force at a frequency corresponding to its rotating frequency (f_r). Let the mechanical impedance of the building frame be as shown in Fig 2. It is shown expanded at the frequency of interest in Fig 3. The exact forcing frequency (f_r) could be anywhere but consider two possibilities at f_a and f_b. If f_r corresponds to f_a, a small amount of vibrating motion will result because

$$\bar{x}_a = F_e/Z_a$$

while a rotating frequency corresponding to f_b will cause motion 100 times larger that may result in

1) failure of the structure,
2) excessive structureborne, airborne, or waterborne noise.

For best results, then, it is necessary to know the following:

a) The unbalance forces at f_r and any secondary frequencies.

b) The impedance of the structure (with equipment mounted) in the region of these frequencies.

c) Resultant motion calculations using (a) and (b) above determine whether performance is acceptable. If not acceptable, then the following opportunities are still available:

1. Vibratory forces can be reduced by better balancing.
2. Structural impedances can be raised at critical frequencies by stiffening, damping, et cetera.
3. An isolation mount can be placed between the rotating equipment and structure to change the impedance of the system.

Fig 6 Endevco force generator and impedance head.

If motion has been measured in terms of acceleration, the formula $F = Ma$ applies, from which is derived $M = F/\ddot{x}$. In this instance the measured force divided by the measured acceleration yields a measure of the effective mass of the system. Again a plot can be made directly on the graph paper of Fig 2 at the intersection of the effective mass line and the frequency line. For greatest accuracy it is necessary to subtract from the measured mass, M_m, the effective mass, M_e, of the part of the measuring system between the sensing material and the specimen; M_s then becomes:

$$M_s = M_m - M_e$$

Phase angle ϕ, which is the phase angle of the velocity signal behind the force signal, can be plotted separately. If acceleration or displacement are measured, it is important to note that

$$\phi = \phi_a + 90° \quad \text{and} \quad \phi = \phi_d - 90°$$

where ϕ_a and ϕ_d are measured phase angles of acceleration and displacement respectively, behind the force signal.

The complete mechanical impedance of the specimen at each frequency can then be defined as:

$$Z_s = Ae^{j\phi}$$

Where A is the absolute value of mechanical impedance taken from Fig 2 for any frequency. To record the real and imaginary components of the mechanical impedance at each frequency, it is conventional to write it in complex notation:

$$Z_s = A \cos \phi + jA \sin \phi.$$

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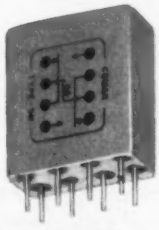

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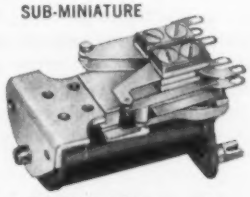

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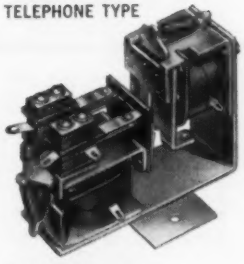

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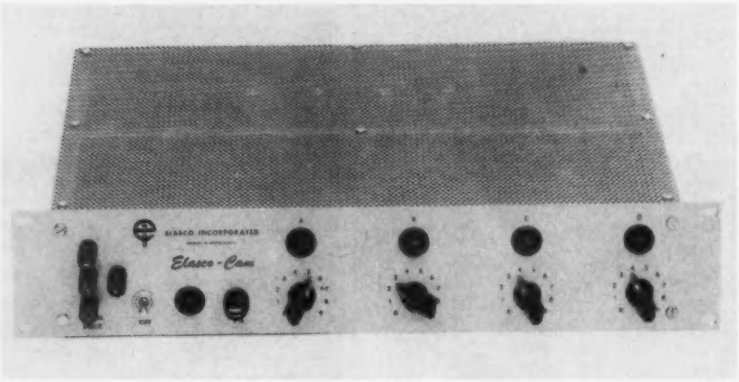

Fig 3 Elasco-Cam Model EC-101.

BASIC THEORY OF ELASCO-CAM

Figure 1 shows a simplified schematic of the basic output circuit and describes its mode of operation. When the input signal passes through zero and reverses in phase, the thyratron fires at a point extremely close to zero, but not exactly on zero, since there is a definite non-zero grid potential at which the thyratron will fire. A high gain pre-amplifier can bring the firing point as close to the point where the input voltage equals zero as may be required. Alternatively, a small bias may be introduced at the thyratron grid so that firing occurs exactly as the input voltage passes through zero. Drift in the thyratron firing voltage naturally causes a shift in the firing point, but this shift may be reduced to a negligibly small value by means of the high gain preamplifier. Furthermore, this type of drift is long term, related to aging of the thyratron, and is readily "calibrated out" by periodic adjustments.

Because the thyratron output is extinguished for half of each cycle, firing must be continually carried on from a definite "off" condition, thus eliminating hysteresis effects. The firing point is extremely sharp, and conduction occurs over most of the half cycle in which the plate voltage is positive, even for small input.

In effect, we have the equivalent of a highly sensitive phase-detector, or relay, with repeatability of hundredths of one percent. A number of such detector circuits can be combined with appropriate summing networks and adjustment potentiometers to make a flexible testing instrument.

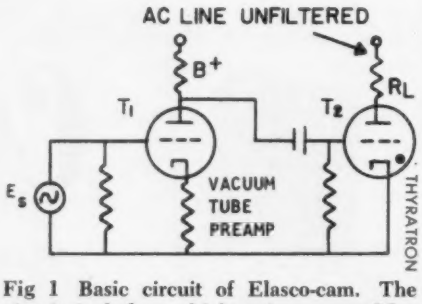

Fig 1 Basic circuit of Elasco-cam. The circuit includes a high gain pre-amplifier of conventional type driving a thyratron. The plate circuit of the thyratron containing the output load is energized from the a-c line, the same line which energizes the transducer whose error is shown as the voltage E_s. As E_s is varied from positive to negative (exhibiting a phase reversal in passing through zero) the phase on the thyratron grid reverses correspondingly. When the grid and plate voltages are in phase with each other and positive, the thyratron fires. When the phase of the grid voltage is reversed, firing of the thyratron is inhibited. Depending upon the gain of the preamplifier and the repeatability of the thyratron firing point, it is possible to have an extremely sensitive circuit which fires the thyratron consistently for a small properly phased E_s. This characteristic sensitivity and high repeatability to an error signal passing through its zero point constitutes the basis of operation of Elasco-cam in more intricate test circuits.

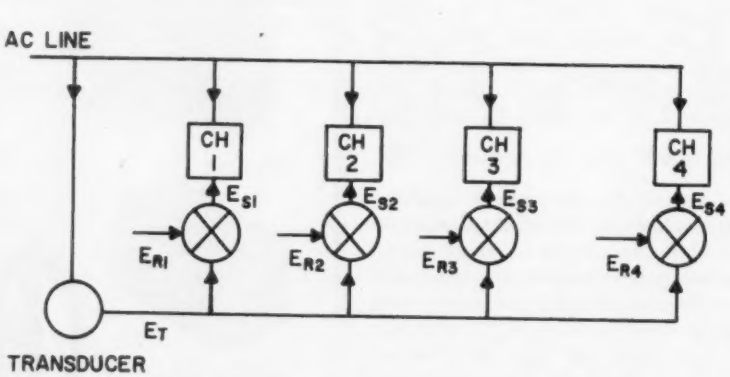

Fig 2 BLOCK DIAGRAM OF GENERALIZED ELASCO-CAM

Power is provided to the transducer and to the individual channels of elasco-cam from the a-c line. The transducer output voltage may be balanced against pre-adjusted reference signals, E_r, in each channel. These are most easily adjusted by means of potentiometers associated with each channel. The difference signals, E_r-E_t=E_s, are applied to the basic detection circuits (of Figure 1) in each channel. As the transducer setting (which may typically be a shaft input) is varied, the individual channels may be caused to fire in turn at precisely repeatable points. In a typical production set up the firing points may be matched against transducer settings as a fast method of measuring accuracy.

TABLE I

1. Number of channels may be varied to suit application. Where an unusually large number are required, units may be used in parallel.
2. Precision potentiometers may be provided in each channel with multiturn dials so that precise firing points can be set by dial readings rather than experimentally. This type arrangement permits direct measurement of transducer output by observation of the firing point of an elasco-cam channel.
3. For high production one or more of the individual channel potentiometers may be replaced by a multi-position switch with an array of precision resistors to constitute an extremely high accuracy voltage divider. The switch may be set in a sequence of positions corresponding to theoretical transducer output, as a measure of transducer accuracy. This use of any one channel does not interfere with the use of the remaining channels. The resistor array may be provided in plug-in form as an extremely convenient means of quickly adapting elasco-cam to the testing of different types of transducers.
4. Where required, the transmission potentiometers may be used in conjunction with the resistor circuitry of 3 above as a means of directly reading deviation from theoretical values. That is, with the transducer in its test position, and the resistor switch set to provide the theoretical balancing, the transmission potentiometers may then be set to cause the elasco-cam to fire; reading directly on its dial the transducer error.
5. The potentiometers for adjacent channels may be ganged with a slight phase displacement. This phase displacement may correspond to a fixed deviation error so that the firing points of the separate channels differ by a fixed voltage increment. Thus, the first potentiometer may set a minimum operating point, while the second sets the maximum operating point.
6. The ganged potentiometer arrangement may be replaced with a resistor array, as described in 3 above, or the ganged potentiometers may be correctly phased while an additional fine-adjustment potentiometer is used to set or indicate error directly.
7. Firing of the Elasco-cam may be used to energize plug-in relays so that complex interconnection of external circuitry is easily carried out.

ELASCO-CAM CIRCUITRY

Figure 2 shows how detector circuits of Fig 1 may be combined with adjustment and summing networks for application in the testing of a-c transducers. In this figure, the transducer setting (which may typically be a shaft position) is varied over its range and the firing points of the separate channels are observed. Transducer settings corresponding to the firing points are compared with theoretical settings to determine the error. Neon bulbs provide simple indication of the firing points for a fool-proof production error detector.

A great variety of devices based upon the Elasco-Cam circuit may be constructed to suit the needs of specific applications, some of which are listed in Table I. The standard four-channel model shown in Fig 3 is expected to meet the needs of most applications.

The reference voltages, E_r in Fig 2, are derived from the settings of stable potentiometers, shown on the front panel of Fig 3. The transducer voltage, E_t, is adjusted to a series of values to be checked, and the reference voltage potentiometers are hand-set to fire the thyratrons at these actual values. It is a simple matter to establish the true values of the reference voltages by means of a precision calibrated voltage divider which may be a highly accurate reference potentiometer, a pair of decade boxes used as a voltage divider, or a standard calibrated transducer. Once Elasco-Cam has been "set up", it is a simple matter to production test additional transducers. The firing points for the separate channels will repeat to within hundredths of a percent. Because of the nulling principle employed, small changes in line voltage, or drifts in frequency will not affect repeatability. • • •

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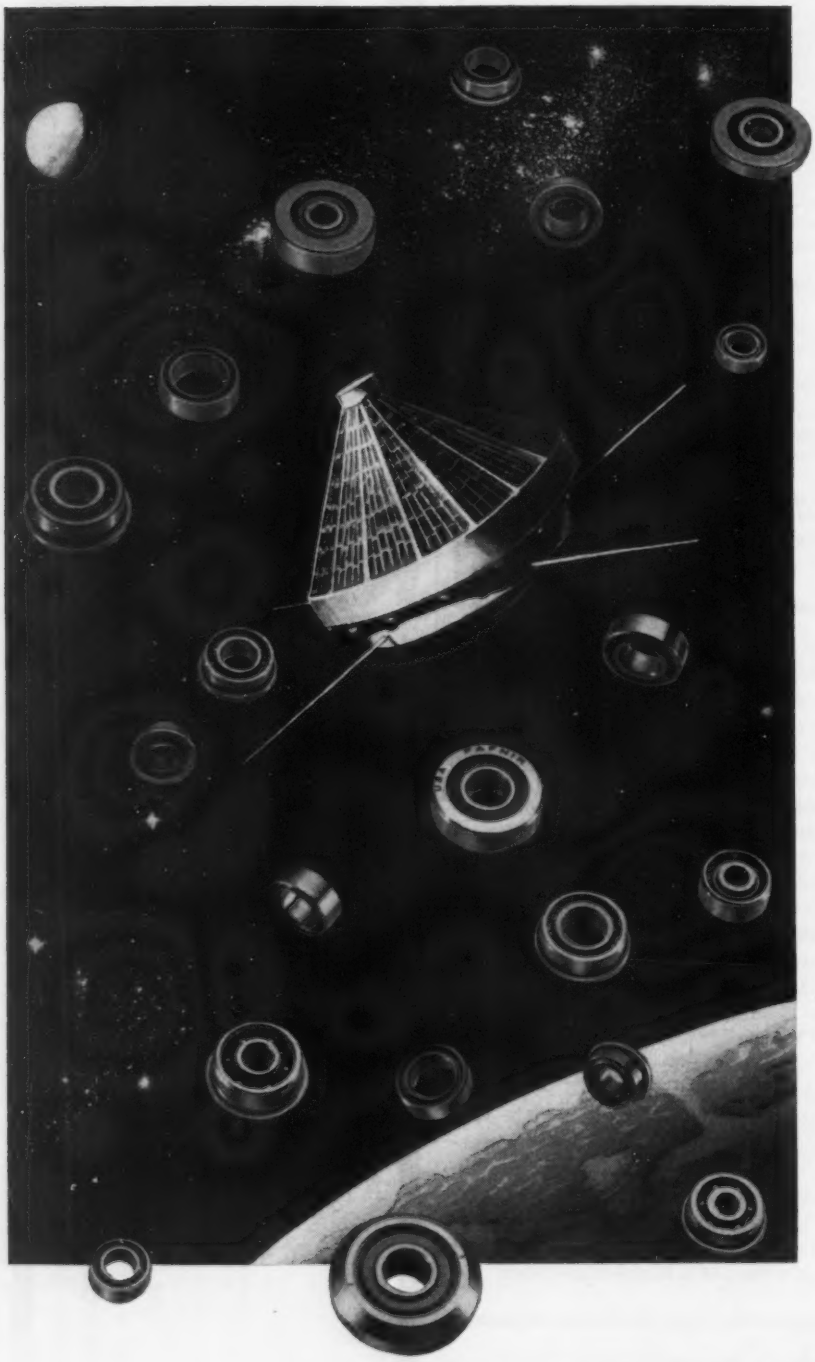

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MATERIALS

FERRITE MATERIAL & COMPONENTS

Magnetic-Gyro Characteristics of Free Electrons in Ferrites Provide Unique Properties

By N. C. Gage, Director of Engineering, E & M Laboratories.

Ferrites are crystalline materials which, like permanent magnets, exhibit ferro-magnetic properties. The major difference between ferrite and iron, such as the laminations used in magnet or transformer cores, is the very high electrical resistance of the ferrite. It is this resistance, which prevents eddy currents from forming within the material, that makes ferrite useful at microwave frequencies.

Ferrous ferrite ($FeO \cdot Fe_2O_3$) which is the parent structure of the family of microwave ferrite material, has a general form which may be written

$$AO \cdot B_2O_3$$

In this expression, A can be one or more chemical elements having a doubly charged atom (divalent cation) and B can be a ferric ion or a mixture of a ferric ion and one or more trivalent cations. If suitable ions are chosen, the resulting ferrites will crystallize in a closely packed cubic lattice, each lattice containing eight divalent and sixteen trivalent metallic ions surrounded by thirty-two oxygen ions. This lattice structure is called a *spinel structure*. To form this spinel structure it is necessary to obtain intimate contact between the various compounds and to provide suitable reaction conditions.

The major metallic components which have been or can be used in ferrite synthesis are: aluminum, barium, calcium, cerium, caesium, chromium, cobalt, iron, lead, zinc, lithium, magnesium, manganese, molybdenum, nickel, strontium, titanium, ytterbium, yttrium, and zirconium. The rare earths listed here plus some others which have recently become economically available in sufficiently pure state are being used to some extent to form a lattice with the garnet structure. These garnets are formed by the substitution of the rare earth for the ferrous oxide. With the large number of available combinations of materials that can be used in the general formula, it can readily be seen that the surface has barely been scratched both with respect to the characteristics of obtainable material and also the functions these materials can perform.

FERRITE PROPERTIES

The one outstanding characteristic which distinguishes ferrite from magnetic metals, such as iron, is its extremely high electrical resistance; a ferrite might have a resistivity from one million to several billion ohms per cubic centimeter. By contrast, iron has a resistivity of only 1/100,000 ohm per cubic centimeter. This difference in resistivity between iron and ferrite enables a high frequency wave (microwave) to see an effective reflector in the case of the iron, while the same wave can enter and pass through substantial amounts of ferrite without excessive reflection or attenuation. A common example of this phenomenon is seen in television transmission where a steel building or other metal structure located in front of the receiving antenna causes poor reception, while a wood or concrete building has little effect on the reception.

The vital property of ferrites which makes them so useful in the microwave art is their unique magnetic permeability. For a clear comprehension of this uniqueness, it is necessary to consider what occurs on the atomic level of magnetic materials.

The magnetic strength of any material is created by the spin of the electrons primarily about their own axes and, on a secondary level, about the atomic nucleus. The spin rate of an electron (and the associated magnetic moment) varies with the distance between the electron and the nucleus (determined by the electron ring) and the charge of the nucleus.

Most of the electrons in any atom are grouped in pairs. The electrons in each pair spin in opposite directions about their own axes and cancel each other's magnetic moments thereby causing the material to be non-magnetic. However, some atoms contain one or more unpaired "free" electrons which provide the magnetism exhibited in certain materials.

MAGNETIC MATERIALS

Magnetic materials usually have a crystalline structure. The orientation and the interatomic bond between the atoms within the crystal strongly influence the magnetic properties of the material.

In crystals that have a strong interatomic coupling and in which there are several atoms with free electrons, the electron magnetic moments may be either parallel or antiparallel, i.e., the electrons are either spinning in the same or opposite directions. Because of the differences in alignment and strength of the magnetic moments, materials which exhibit ordered magnetism are normally classified as being ferromagnetic, antiferromagnetic, or ferrimagnetic:

- In a *ferromagnetic* material, the electron magnetic moments within each crystal are aligned parallel under the influence of an external magnetic field. This results in a strongly magnetic material.
- In an *antiferromagnetic* material, the electron magnetic moments within each crystal are equal and, under the influence of an external field, the magnetic moments become aligned antiparallel. Thus, the magnetic moments are cancelled and the material exhibits no

magnetism.

• In a *ferrimagnetic material*, the electron magnetic moments are unequal and, under the influence of an external field, the magnetic moments become aligned antiparallel. Because the magnetic moments are unequal, only part of the magnetism is cancelled, resulting in a material which exhibits weak magnetism. Ferrites fall in this class.

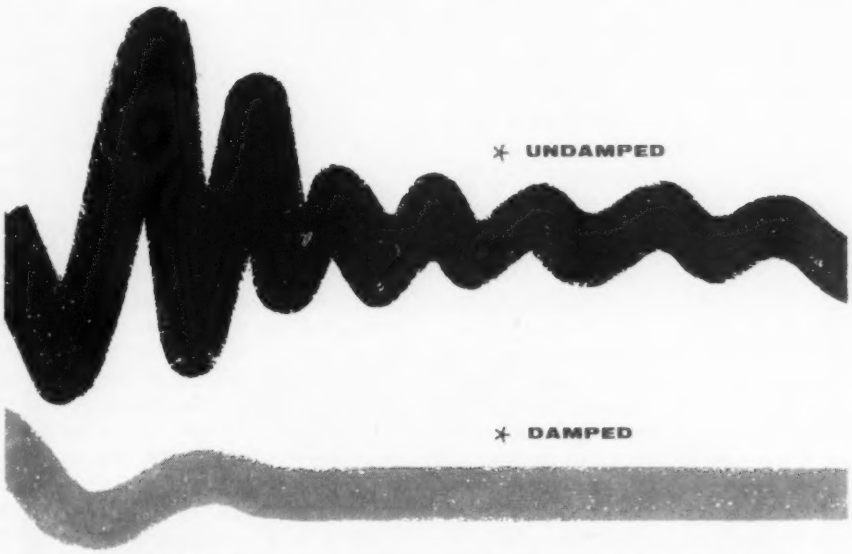
Interatomic coupling within the crystal is strongly dependent upon temperature. As the temperature is raised beyond what is called the "Curie" temperature, thermal vibrations overcome the coupling force and the magnetic moments become randomly aligned. Such crystals, except when under the direct influence of an external field, exhibit no magnetism and are called *paramagnetic*. Many materials are paramagnetic even at room temperature since this temperature is sufficient to exceed the Curie temperature of the material. As will be indicated later, the Curie temperature is one of the limiting factors in the use of ferrite at microwave frequencies.

EFFECT OF ELECTRON SPIN

As the free electrons within the ferrite spin about their own axes, they function as magnetic gyros. When a fixed magnetic field is applied to these magnetic gyros, it aligns the spin axes of the electrons. In the process of moving its magnetic spin axis into line with the applied magnetic field, the electron tends to precess, just as any other gyro does when the spin axis is disturbed. The rate of precession is proportional to the strength of the aligning field. If an auxiliary rotating field is now applied perpendicular to the aligning field, one of two things will occur. When the rotation of the secondary field is opposite to the direction of electron precession, the field will have no effect on the electron. If the field rotation is in the same direction as that of the electron precession, the field causes the electron spin axis to wobble, just as a spinning top does before it falls down.

To see how the properties of ferrite materials that have been discussed come into play at microwave frequencies requires recognition that microwave energy travels, not as a stream of electrons, but as a coherent electromagnetic wave. Within the conductor (usually a rectangular pipe called a waveguide), this magnetic wave or field moves in groups of closed concentric rings. As each of the rings passes any fixed point within the waveguide, the magnetic field appears to be rotating. The direction of rotation reverses with the direction in which the wave is travelling in the waveguide, while

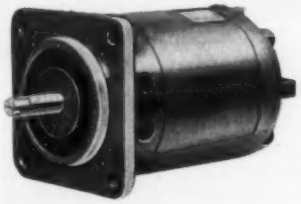
SOLUTION
TO A
HUNTING
PROBLEM



DAMPED HYSTERESIS SYNCHRONOUS MOTOR — MODEL FBC3830H-41

It is characteristic of hysteresis synchronous motors that any variation in the applied voltage, frequency, or load will cause an initial hunting or oscillation of the output shaft. However, this condition can be controlled **imc** hysteresis synchronous motor, model FBC3830H-41 is designed to minimize hunting or oscillating characteristics.

The built-in damping capabilities of this 3 speed motor results in fast return to the original steady state condition. Single speed as well as multiple speed damped units are available.



SPECIFICATIONS

FREQUENCY:	60 cps
VOLTAGE:	115 volts, single phase
SPEED:	3600/1800/900 rpm
RATED HORSEPOWER:	1/20 - 1/40 - 1/100
INPUT POWER:	2.2/1.4/0.9 amps
RATED TORQUE (in-oz):	14/14/11

APPLICATIONS — Ideally suited to data and video recorder applications, machine tool controls, computer applications, or any application where low noise, low initial hunting of output shaft, and quick speed recovery is required. **May imc assist in solving your hysteresis synchronous motor hunting problems?**

Write for additional information, or send for hysteresis synchronous and torque motor catalog.

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EASTERN DIVISION
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Westbury, L.I., N.Y.
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OTHER PRODUCTS: propeller and vane-axial fans/centrifugal blowers/heat exchangers/dynamotors and inverters/servo motors and motor tachometers/torque motors/induction motors/dc motors

*Shown above are illustrations of initial hunting or oscillation and constant speed recovery patterns of damped (damping ratio of 0.7 to 0.9), and undamped hysteresis synchronous motors.

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the speed of rotation is proportional to the frequency of the microwave signal.

FERRITE APPLICATIONS

If a strip of ferrite is now placed inside the waveguide and subjected to a magnetic field, the electron spin axes will tend to align themselves perpendicular to the aligning magnetic field. In the process of being aligned the electrons will begin to precess. If the strength of the aligning field is such as to cause the precession rate to be equal to the frequency of the microwave signal being transmitted through the waveguide, the waveguide (with its associated ferrite strip and magnet) will function as an *isolator*. Any electromagnetic wave transmitted through this isolator in the direction which causes the wave or field rotation to be opposite to the precession of the electrons will have no interaction with the electrons and the wave will pass through the isolator without loss. Any electromagnetic wave transmitted from the other end of the isolator will have its field rotating in the same direction as the precession of the ferrite electrons. The energy of this wave is dissipated as it passes through the ferrite in causing the electron spin axes to wobble. This energy is then converted to frictional heat within the ferrite. Thus, the isolator functions as a one-way valve by allowing signals to pass through unimpeded in one direction and prevents signals from going through in the other direction.

We can now see why ferromagnetic material is not useful at microwaves even though it is magnetically stronger than ferrite material. Since the electromagnetic wave is reflected from the ferromagnetic material, it cannot interact with the spinning electrons within the material. In the case of ferrimagnetic material, as the wave passes through more and more of the material, more and more of its energy can be dissipated. In the matter of a fraction of an inch it is possible to dissipate a considerable portion of the energy of undesired signals. For example, E & M Laboratories is producing a series of practical isolators which are as small as ½-inch in length.

In actual practice, there is no such thing as a perfect isolator which will absorb all of the energy of a signal transmitted in one direction through the isolator and none of the signal transmitted in the other direction. An isolator is affected by imperfections in the basic ferrite material, imperfections in the grinding and shaping of the ferrite, environmental temperature, the difficulty in getting the precise external field strength and aligning the ferrite with the magnet, and other problems created by the combined effects of the ferrite, magnet, and waveguide on the signal. Because of this, all isolators evidence insertion loss or some absorbtion of the signal which is supposed to be unaffected by the ferrite and also do not completely absorb signals in the opposite direction.

One other factor worthwhile noting about the isolator is the effect of the Curie temperature of the ferrite. Since the energy from the absorbed signal is converted to frictional heat within the ferrite, the temperature of the ferrite is raised. With low power signals this usually is not a problem because the heat can be dissipated from the walls of the waveguide before the Curie temperature of the material is reached. As the power to be dissipated gets higher, the problems increase proportionately. It is frequently necessary to find materials with higher Curie temperatures, to cool the walls of the isolator with air or coolants, and to reduce the insertion loss.

In the case of the isolator, the external field strength was made such that the electron precession rate would equal the frequency of the microwave signal. When the magnetic field strength is changed, causing the electron precession rate to vary from the microwave signal frequency, the microwave energy, instead of being absorbed by the ferrite, is merely diverted. The ferrite electrons still ignore signals coming from one direction; however, signals coming from the other direction undergo a slight change of frequency, i.e., the phase of the signal is rotated slightly. This characteristic of ferrite is employed in Faraday rotator devices.

As an example of the use of a rotational device, consider a typical radar system that has a single common antenna for both transmission and reception of signals. If the transmitter signal were to enter the receiver unimpeded, it would either burn out part of the receiver or the receiver would have to be made so insensitive as to render it useless for all practical purposes. To avoid this occurence, a ferrite component employing the Faraday rotational principle, called a duplexer, is employed. In the duplexer, the high-power transmitter signal is rotated sufficiently to prevent its entering the receiver. Also, the weak received signals are rotated so that all of the signals arrive at the receiver, and none are side-tracked into the transmitter.

Regardless of the several limitations of ferrite components, such as the Curie

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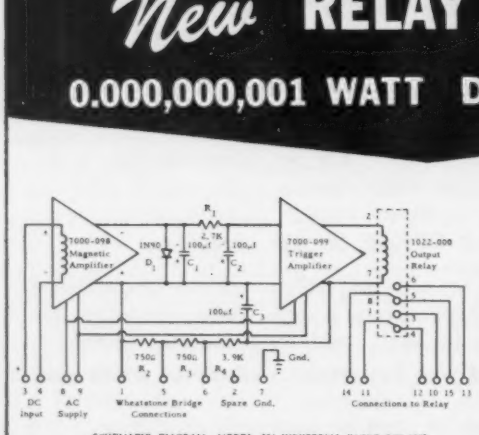
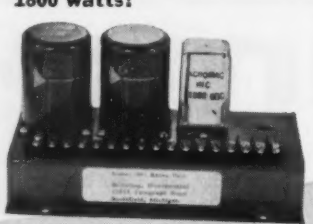


SCHEMATIC DIAGRAM, MODEL 301 INDUSTRIAL "ACRO-RELAY"

This industrial "ACRO-RELAY", Model 301, closes its output relay with a DC signal of 1.0 microamp and 1.0 millivolt into its 1000 ohm input winding—an input power of only 10^{-9} watts! It is the most sensitive, high-reliability industrial relay unit available. The input magnetic amplifier drives a trigger amplifier which drives the DPDT output relay . . . controlling up to 1800 watts!



Model 301 units available from stock for IMMEDIATE DELIVERY!

Price for 1—5 units: $98.75 each. Full details available in Bulletin No. 30-A.

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temperature, they have several advantages that make their use in microwave work almost mandatory. Principally, ferrite components are much more efficient than other devices for isolators, duplexers, electronic attenuators, electronic phase-shifters, etc. In addition, most ferrite components are passive and do not require any driving power to function. Also, as passive elements, they have an infinite life, even under the most adverse overload conditions, making them extremely reliable for use in missiles, remotely-controlled-microwave links and airborne radar systems.

The future of the ferrite industry is limited only by the vision, talents, and energy of the scientists and research engineers who apply themselves to this field. There are so many possible combinations of materials that would make useful ferrites, it would take considerable time just to prepare and test them. Areas of present research in ferrites range from uncovering new materials for use in existing components and investigating use of available materials in new components, to preparation of new materials for entirely new components. Within the next few years, we can expect a whole new series of ferrite devices to emerge from research laboratories. • • •

For more information on ferrite devices
Write No. 183 on Inquiry Card.

High Density Foam for Packaging

Supplied as an integral part of custom suspension packages or separately in the form of corner pads or blocks, a high-density polyurethane foam for packaging delicate electronic equipment offers a high resistance to shock impact with minimum thickness and cushioning area. It has high compression strength, low compression set, high resistance to vibration, excellent uniformity and performs over a wide range of static loading, from 0.5 to 2.0 psi. Leewood Corp., Lowell. Mass.

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Epoxy Molding Compounds

Hailed as a major breakthrough in rapid, mass production of computer and missile components, epoxy molding compounds are versatile plastic materials with soft-flow molding characteristics that make possible high-speed molding of electronic and electrical parts from materials previously found unworkable in manufacturing processes. The compounds are said to offer a degree of production reliability never before attained. American-Marietta Co., Adhesives, Resins & Chemical Div., Seattle, Washington.

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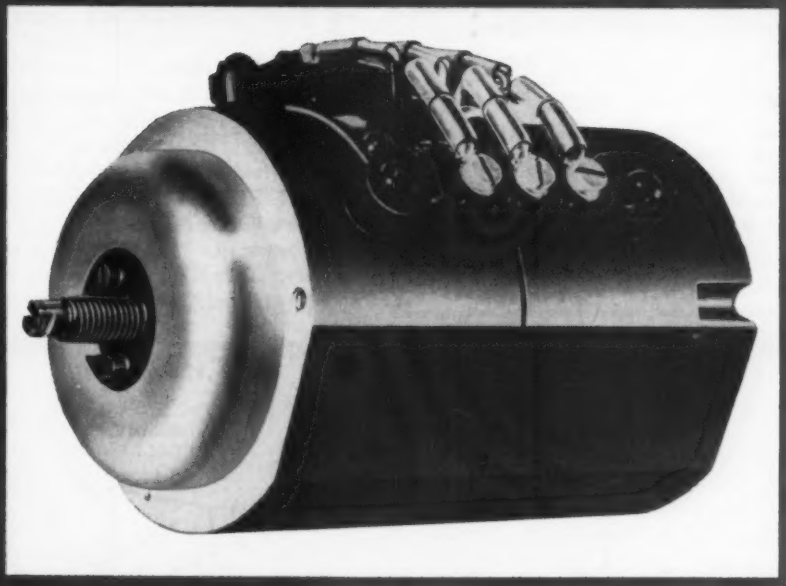
two IN one

DIFFERENTIAL SYNCHRONIZES AUTOMATICALLY



Kollsman's synchronous differential combines two hysteresis synchronous motors and mechanical differential all within one $3^{45}/_{64}$" inch housing. Package weighs only 26 oz.

One synchronous motor is connected to the control or master frequency; other is connected to the supply which is to be controlled. When the two frequencies synchronize, output shaft of the device remains stationary. As one frequency changes with respect to the other, the output shaft rotates at a speed equal to one-half the difference in speed of the two synchronous motors. Thus by connecting the output shaft to the mechanism regulating the frequency or machinery to be controlled, synchronization can be achieved.

OTHER PRODUCTS: SYNCHROS RESOLVERS SERVO MOTORS MOTOR GENERATORS INTEGRALLY GEARED UNITS INDUCTION GENERATORS DRAG CUP MOTORS SYNCHRONOUS MOTORS PERMANENT MAGNET GENERATORS VELOCITY AND INERTIA DAMPED UNITS . . . AND SPECIAL DESIGNS.

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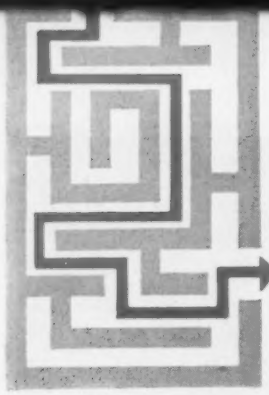


DESIGN TIME SAVER

GRAPHICAL CALCULATION OF SYSTEM NOISE FIGURES

by Douglas E. MacLaughlin and Herbert F. Spirer

Spirer Associates, Stamford, Conn.

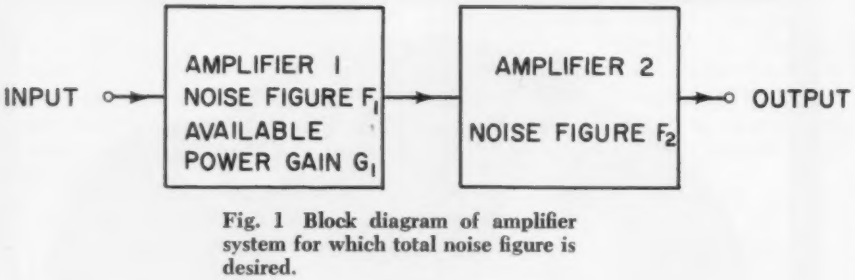
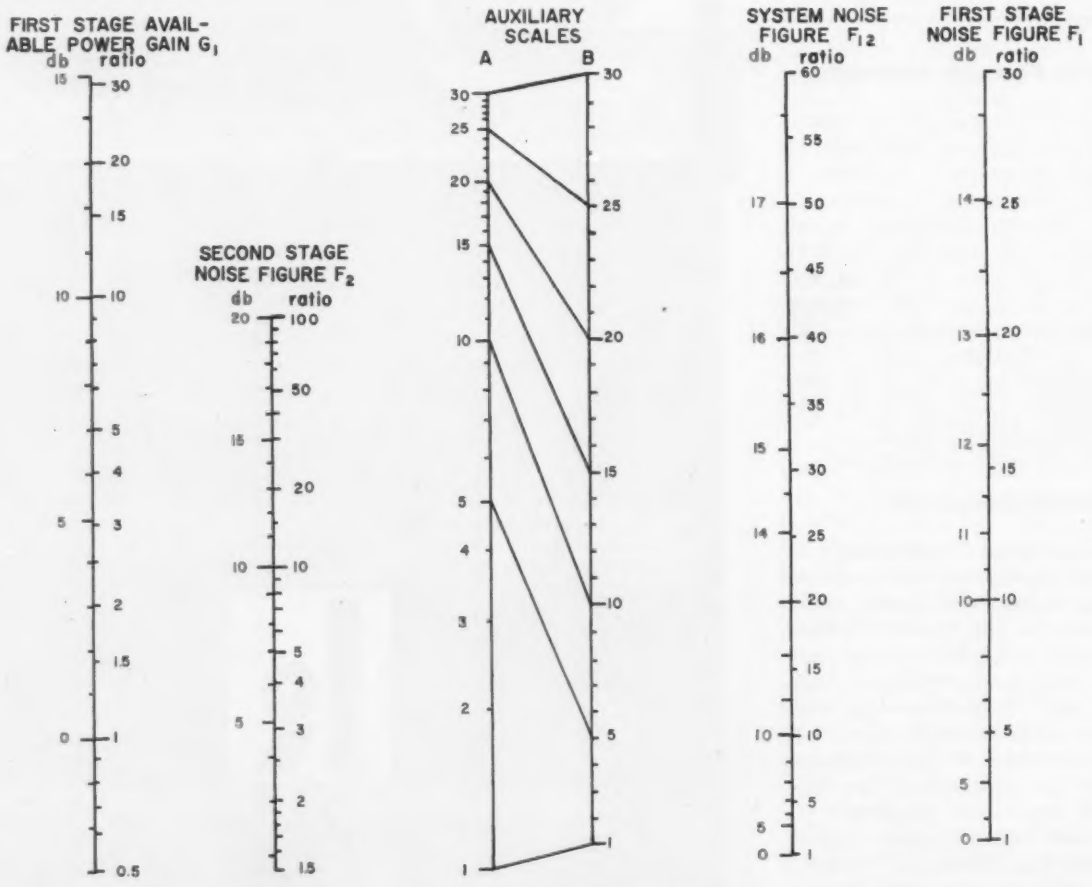


Fig. 1 Block diagram of amplifier system for which total noise figure is desired.

System and circuit design calculations can be speeded by use of nomograms for obtaining the resultant noise figure of a two amplifier combination. Typical cases where such calculations are required are: during the design of receivers where the gain of the first stage is low enough so that the second stage noise figure and first stage gain must be considered, and during the design of communications systems in-

CHART 1



volving receivers combined with amplifiers or multicouplers.

A typical amplifying system for which the net noise figure is desired is shown in Fig 1. In general the noise figure F of a network is defined as the ratio of the mean output noise power to the noise power generated by a resistor equal to the input impedance at room temperature: the noise figures F_1 and F_2 of Amplifiers 1 and 2 are so defined. The available power gain G_1 of Amplifier 1 is defined as the gain of a "noise-free" amplifier. With these definitions, the total noise figure F_{12} of the system as a whole is given by the relation

$$F_{12} = F_1 + \left(F_2 - 1/G_1 \right) \quad (1)$$

All quantities in this equation must be specified in power ratios, *not* db.

Charts 1 and 2 are nomograms which solve this equation graphically. Chart 2 is simply an expansion of the lower portion of Chart 1, resulting in increased accuracy in the region of small gains and noise figures.

Equation (1) is actually solved in two steps. First, the relation

$$F_{12} - F_1 = \left(F_2 - 1/G_1 \right)$$

is solved; that is, given F_2 and G_1, the quantity $F_{12} - F_1$ is found. Then F_{12} is found simply by adding F_1 to the quantity $F_{12} - F_1$. All quantities are plotted both as ratios and in db on the charts, so conversion is not necessary.

The nomograms are used as follows. First, a straightedge is passed through the points corresponding to the known values of G_1 and F_2 on the appropriate scales. The resultant value of $F_{12} - F_1$ is read from Auxiliary Scale A. This value is noted. The straightedge is then transferred so as to pass through the same value of Auxiliary Scale B, and also through the known value of F_1. The value of F_{12} is then read, and the operation is complete.

Both nomograms are used in the same way. The connecting lines between Auxiliary Scales A and B aid in the rapid and correct transferral of numbers between the two scales.

It is possible that values of G_1 and F_2 will occur that do not fall on the scales of Chart 2, but which give a value of F_{12} which could be read to better accuracy on the expanded chart. In this case, the number obtained from Auxiliary Scale A of Chart 1 may be transferred directly to Auxiliary Scale B of Chart 2.

One should always be consistent in the choice of units: i.e., the ratio and db scales should not be confused. The db scales have been printed in color to make it easy to differentiate the two.

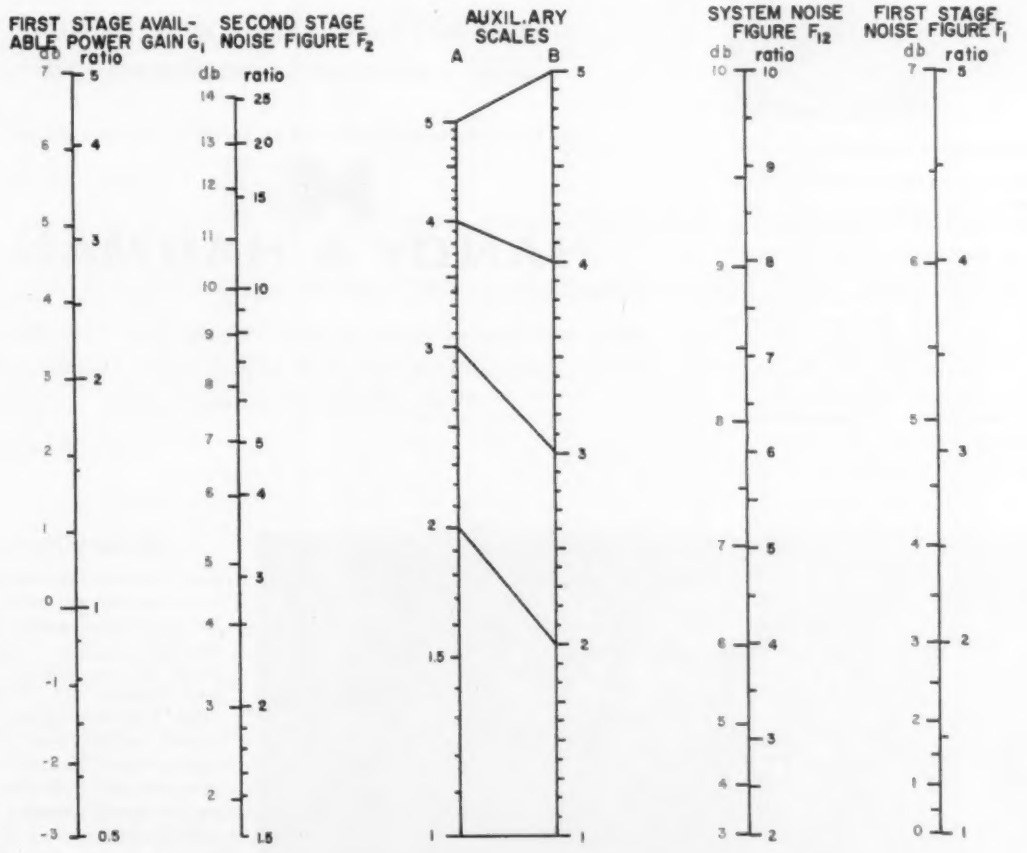
With a little practice it is possible to obtain system noise figures quite rapidly, and with an accuracy of approximately ½ db. It is evident from Equation (1) that for high values of G_1, $F_{12} = F_1$, so that it is not necessary to use the charts in this case. • • •

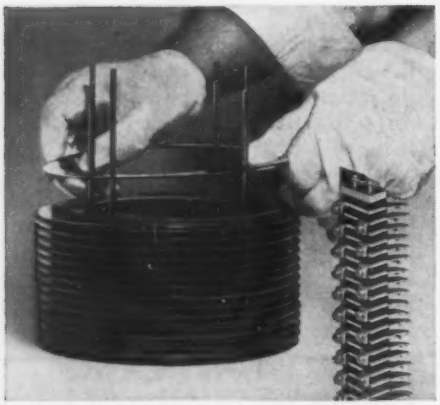
TO USE CHARTS 1 and 2

Pass a straightedge through the known values of G_1 and F_2 on the appropriate scales on chart 1. Note the point at which the straightedge passes through Auxiliary Scale A. Transfer this value to Auxiliary Scale B and pass the straightedge through it and the known value of F_1. Read the value of F_{12}.

If the value of F_{12} falls on the lower portion of the scale and cannot be read with sufficient accuracy, use Chart 2. Values read from Auxiliary Scale A of Chart 1 may be transferred directly to Auxiliary Scale B of Chart 2.

CHART 2

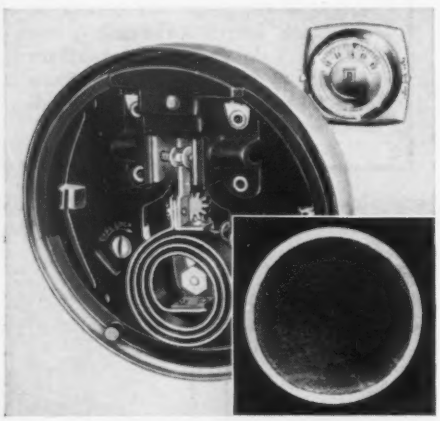




Slip Rings?

To provide excellent electrical properties and long equipment life for slip rings, we manufacture and supply fine and coin silver in the form, size, finish and degree of hardness most convenient for the manufacturer and least productive of scrap.

Photo courtesy of Breeze Corporations, Inc., Union, New Jersey



Adjustable Contacts?

The Handy & Harman Bimet shown here is used as an adjustable contact in a Rimset thermostat for control of residential heating, cooling and air conditioning. It is made of fine silver for optimum conductivity and reliability, and clad with bronze to give a more machinable, easily threaded surface. Handy & Harman bimetals give you uniformly clad precious metal just where you need it, with no excess. Available in gold and silver and their alloys in strip, overlays, inlays, edge lays and thrulays.

Photo courtesy of Penn Controls, Inc., Goshen, Indiana

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Gold and silver...and their alloys...possess a combination of characteristics that offers unique advantages to the electronics and electrical industries. Their excellent electrical and thermal conductivity makes them ideal for a vast range of applications, particularly in subminiature components. Their ability to resist corrosion imparts long service life and dependability to critical control items. The fact, too, that they can be obtained in so many convenient forms...wire, strip, sheet, powder, bimetals, flakes and plating anodes...lends them unusual versatility.

These are only a few examples of the ways in which Handy & Harman precious metals are used in the electronics and electrical fields. Perhaps they will suggest some ideas to help you apply them advantageously in your own products or operations. Our technical staff invites your inquiries. No obligation.

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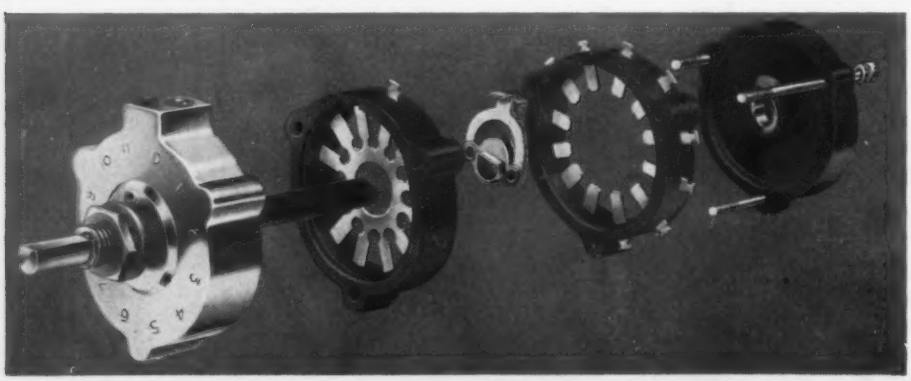

Rotary Switches?

Low contact resistance and ability to withstand corrosion make silver ideal for switch parts. The stationary contacts of this rotary switch are made of fine silver...the multiple leaf brushes are of durable silver alloy. Life tests of one million operations, representing several years of normal use, show that "Zero" resistance of 0.001 ohm through the switch body changes by less than 0.0005 ohm.

Photo courtesy of Leeds & Northrup Company, Philadelphia, Pa.

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COMPONENTS DIGEST 20

Part II

ELECTRIC TIMING MOTORS

Many timing mechanisms depend for their performance on constant speed electric drive motors. A common example is where a driven cam shaft actuates a number of microswitches in a preset sequence. Here the accuracy depends upon the accuracy of the drive motor. This arrangement is extremely flexible. The gear reduction from motor to cam shaft permits a wide time interval range. The ratings of the individual microswitches are conveniently selected to suit the application. Common application arrangements and their advantages and disadvantages are described in Table I. In this second part of Components Digest 20 on Timers, we consider in detail the application and limitations of timing motors.

BASIC TYPES OF TIMING MOTORS

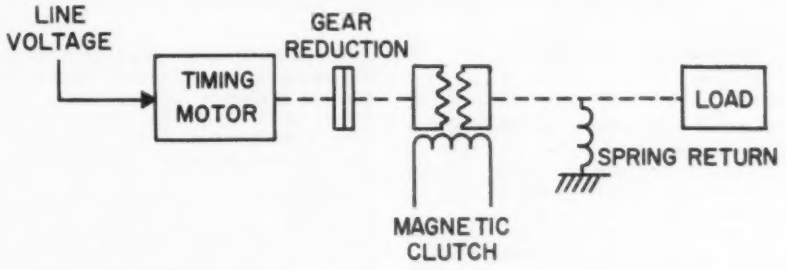
Selection of a timing motor depends vitally on the available power supply, which may be ac or dc, determining the choice of an ac or dc motor. Most commonly the ac motor will be synchronous, with a speed exactly related to line frequency. The factor of proportionality is defined in the equation:

$$N = 120\, f/p$$

$N = rpm$
$f = cycles/second$
$p = poles$

A synchronous motor will on the average be exactly as correct as the line frequency, rotating through an angle corresponding to a pair of poles during each cycle. During the course of a single revolution, however, or for brief periods during transients, the instantaneous speed may fluctuate substantially though without skipping a cycle. Severe load or line transients can cause the motor to "drop out" briefly, with a permanent loss of angular displacement. Instantaneous speed variation of a synchronous motor is called "hunting". Hunting is not very important in timing applications.

Induction motors may be used in constant speed applications, but they are relatively inaccurate because of their "slip", or speed reduction below that of a synchronous motor. Their principal use is in those applications where significant shaft power or high starting torque is required. Induction motors are not often used in timer ap-



TYPICAL ARRANGEMENT FOR A SPECIFIC APPLICATION

TABLE I ● TIMING MOTOR APPLICATION FACTORS

The typical constant speed timing motor incorporates a gear reduction. A friction slip clutch may follow the gear reduction to limit destructive torques which may occur on the low speed shafts in the event that something jams. In this illustration a magnetic clutch, when energized, iniates the timing cycle. When de-energized, a spring return restores the load to a starting position against a limit stop. A clutch-brake may be substituted for the magnetic clutch-spring return combination where it is desired to stop and hold the output load in a fixed position. Perhaps a position sensitive contact associated with the load can de-energize the clutch brake to achieve the hold condition.

The gear train may be integral with the motor as a gearhead, or it may comprise an array of gears external to the motor. Usually the bulk of the reduction is contained inexpensively and compactly within the gearhead, while the external gearing is selected for convenience in coupling shafts, or where provision must be made for making slight adjustments in ratio. It is relatively easy, using kits available from several manufacturers, to put together gear trains having a wide range of ratios, depending on the application.

In more complex mechanisms, automatic speed changing is possible by methods similar to gear shifting an automobile transmission. Speed changing is very easily accomplished using magnetic clutches, see for example Components Digest 13 on Magnetic Clutches and Brakes in the March 1960 issue of Electromechanical Design.

The driven load may consist of a cam shaft and microswitches or a heavy drum with easily set pins for contact actuation, a chart drive mechanism, etc. The lower limit of accurate time interval may depend upon how quickly the motor can bring the output load up to speed. Motor ratings are discussed in Table IV.

Other output members include digital counters which provide a measure of time interval. Included among these are elapsed time indicators. A potentiometer output may be used to generate a linear or nonlinear function of time. The variety of application devices is enormous.

plications.

Stepper motors are in a sense a variety of synchronous motor responding to a pulse input by a definite increment of angular rotation. They will be discussed in greater detail in a subsequent Components Digest.

Table II presents the important performance characteristics of synchronous and induction machines for timing applications. The table includes a description of the several types and a discussion of important environmental characteristics.

The ac synchronous timing motor is unbeatable in accuracy where a sufficiently stable and accurate power source is available. In most military applications however, the power frequency is too variable, typically 380 cps to 420 cps, a band of ±5%. In such instances, as well as in instances where ac is not even available, dc timing motors are required. These are usually a conventional type — the permanent magnet armature-excited dc motor. The armature, when energized from the line through the brush contacts, rotates in the permanent magnet field so as to generate a counter emf opposing the applied voltage and limiting the flow of current. Very approximately at light shaft loads, shaft speed is proportional to applied voltage. Current taken by the motor must interact with the permanent magnet field to provide the required shaft torque. Developed torque will be quite accurately proportional to current. Of course, the resistance drop in the armature winding and in the brush contacts means less counter emf, and less speed. Thus there is a natural loss of speed with increasing shaft torque. Table III summarizes the characteristics of this type dc motor for timing applications. Note that speed depends primarily on applied voltage, and to an important but somewhat lesser extent on variations in circuit resistance, which might occur over a range of temperatures. Temperature error is a very serious error component in highly accurate dc timing motors. Light and constant shaft loads are important to secure highest accuracy.

TABLE 2

Characteristics of Synchronous and Induction Motors

SYNCHRONOUS MOTORS

Exact relation between speed and line frequency.

Speed independent of line voltage and wave form distortion as long as synchronism is maintained.

Pull-out torque and starting torque vary as the square of the applied voltage.

Input power goes up as square of applied voltage where shaft load is negligible.

Hunting is a superimposed low frequency modulation of instantaneous speed, with average speed held constant. Hunting may be important where output is driven at high speed.

Very special designs available where it is economical to produce a unit with a large number of poles (low synchronous speed) in a small size. These units are at their best where load demand for shaft power is almost negligible. Low speed means fewer gear reduction stages and longer bearing life.

Most economical starting means is generally by a shading coil, which does not have high starting torque. Thus bearing friction must be very low, even at low temperatures. Capacitor starting provides more starting torque in larger units.

Hysteresis motors employing a motor of permanent magnet material are commonly employed to develop synchronous torque.

Reluctance motors using a notched rotor are often used as synchronous drives. These develop relatively poor starting torque which can be boosted by providing a small amount of induction motor action on top of the synchronous behaviour.

With very many poles, synchronous speed is so low that the motor readily synchronizes with a minimum of starting torque.

Extremely high accuracy can be obtained from synchronous motors driven from a temperature controller crystal oscillator source. Somewhat lesser accuracy is obtainable from a tuning fork supply. However, these supplies are often cumbersome.

INDUCTION MOTORS

Only useful in larger sizes, where their output power and efficiency permit them to operate at near synchronous speed.

Synchronous speed is same as for a synchronous motor, but motor "slips" or falls below synchronous speed by an amount proportional to the developed load.

For a particular load, slip increases with temperature approximately in proportion to the increased resistivity of the rotor bar material.

Slip decreases inversely with the square of the voltage.

Power input and power output capacity increase with square of voltage.

Starting torque increases as the square of voltage.

A large number of poles is not available as conveniently as in a synchronous motor.

Starting torque is commonly obtained through use of shading coil or a starting capacitor.

TABLE 3

D-C TIMING MOTORS CHARACTERISTICS

Counter emf equals difference between applied voltage, and resistance drop in brushes and winding.

Speed is proportional to counter emf for fixed permanent magnet poles. Therefore speed changes with applied voltage.

Current is proportional to applied shaft torque. Generated torque is the product of permanent magnet flux and armature current. At very light shaft loads current is very low. With low current and low resistance drop, speed is approximately proportional to applied voltage.

As temperature increases, resistance drop increases, reducing speed.

As temperature increases, the permanent magnet strength decreases. This means that the motor must turn faster to generate the required counter emf.

The ungoverned motor is useful for applications requiring no more than ±10% speed accuracy at nominal voltage.

Very small diameter commutators are generally used for low peripheral speed, and reduced wear.

Self polishing low friction brushes at low density are required for long life. Special environments, particularly those associated with the atmosphere, substantially affect brush life.

Life of several thousand hours is generally obtainable. High field strengths which result in low rotor speeds contribute to life.

Filters are usually required either on the motor or in its application equipment for long life.

A wide range of voltage ratings is obtainable depending only on the armature winding. High voltage motors can be driven by plate current of a tube; low voltage units can operate from a storage cell.

Speed may be adjusted precisely by suitably magnetizing the permanent magnet.

Note: The A. W. Haydon Company of Waterbury, Conn. employs a novel construction based upon winding the armature on a non-magnetic conducting cage. This cage has eddy currents induced in it due to its rotation in the permanent magnet field, which slows the unit down. The cage conductivity falls at high temperature leading to a reduction in eddy currents and a tendency to increase in speed, compensating for the natural slowing down at high temperature. This compensating method is good and inexpensive, although wasteful of shaft power., Since there is no iron in the rotor these timing motors have a smooth starting torque, free from cogging.

GOVERNED DC MOTORS

For good accuracy in dc motors, some means of speed governing must be provided. A convenient and commonly used method is to provide a set of centrifugally operated contacts on a plate fixed to the motor shaft with a pair of slip ring brush contacts for connection in the motor circuit. The centrifugally operated contacts may be connected through the slip rings in series with the motor armature. The contact is normally closed in this method so that line voltage is applied directly to the motor. When the governed speed is reached, the contacts open, which may either open the motor circuit to slow down the motor, or may insert a dropping resistor in series with the armature. A dropping resistor is generally required and may be so adjusted to minimize the amplitude of hunting to achieve accurate speed control. A screw-type adjustment is often used in setting the contacts to operate at a specific governed speed. The oscillation range of the governed speed must not be so tightly restricted as to require too small a contact clearance, which may prevent proper functioning over the temperature range, or with small changes in mechanical dimensions due to ageing of materials. The contact must have room to open properly. Too high a hunting frequency leads to reduced contact life.

For good accuracy the springs associated with the centrifugal governor must be free of internal strains which may gradually shift the governing point. The spring material characteristics should be relatively independent of temperature to within the required limits of accuracy. The design must definitely take into account such environmental factors as shock, vibration, and acoustic noise which may cause faulty operation, as in most relay type devices. And of course, contact ratings must be adequate for the life of the unit and protection must be provided against salt spray and humidity which can easily lead to faulty operation.

Wear in the contacts disturbs the effective contact setting. Materials must show a minimum tendency to stick, since sticky contacts can lead to wide speed fluctuation.

COMMERCIAL TIMING MOTORS

This section brings together descriptions of the construction and performance of various commercial timing motors based on information submitted by manufacturers in response to a questionnaire. Characteristics of individual designs will suggest what to look for in motor selection. The characteristics of motors described are typical of good current designs, and may be modified over a wide range to suit application requirements. Table IV lists major selection factors.

TABLE 4

SELECTION FACTORS FOR TIMING MOTORS

Power supply

A-c or d-c, precision of a-c frequency, waveform
Voltage range. What voltage and frequency?

Type of motor

A-c synchronous or induction.
D-c governor controlled.
D-c ungoverned.

Required shaft speed

Accuracy with respect to specific operating conditions such as voltage, frequency, temperature and load variation, and vibration.

Power limitations

Current drain while running, and during starting.

Rotation

Clockwise, counter clockwise, reversible.

Load requirements

Starting torque, running torque at output shaft; peak torques, duty cycle, load application rate.

Gearhead

Backlash, loading, accuracy of mounting surfaces, run-out.

Inertia of load

May effect synchronizing of motor if load inertia reflected through gearing is of same order as or greater than motor inertia.

Life requirements

Under what specific operating conditions.
Operating temperature range
Radio interference specifications
Other environmental requirements

Accuracy of an escapement clock and the power of an electric motor are combined in a novel dc timing motor by the **A. W. Haydon Co.** to keep rate independent of load, line and temperature variations.

Power pulses at full line voltage are applied to a small motor at intervals controlled by a jewelled escapement, with the pulse duration determined by travel of the motor. This method holds motor travel constant during each time interval regardless of load (within rating). As a result beat rate is held constant within ± 0.1 percent for line voltage variations of ± 20 percent and load variations from zero to full load.

As a primary source for precision time control, the balancing wheel and hairspring mechanism has several advantages. It can be designed to be

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This is no place for a beginner or a drone. What others treat as the "State of the Art", we consider commonplace, and you'll need both training and experience to qualify. We prefer an E. E. who is familiar with test equipment problems and inspection techniques. Past association with military electronics equipment or experience in precision measurement of mass produced items would help to equip you for this position. Machine Shop experience would also be useful.

If you can qualify, we promise you an exceptionally rewarding spot with one of the nation's most vital industries. We offer unusually generous company benefits in a Midwestern community which is famous for its beauty and low cost-of-living. All replies will be strictly confidential.

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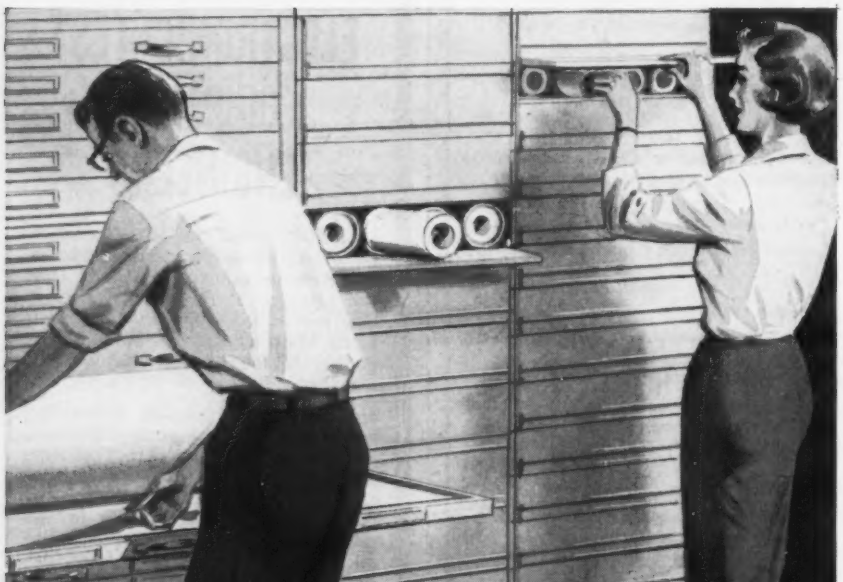

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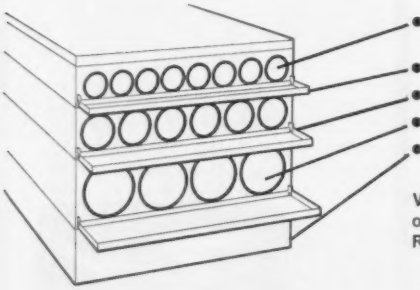

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COMPONENTS DIGEST

relatively unaffected by changes in position, temperature, magnitude of driving force, vibration or gravity, and in addition requires relatively slow motion as compared with a tuning fork.

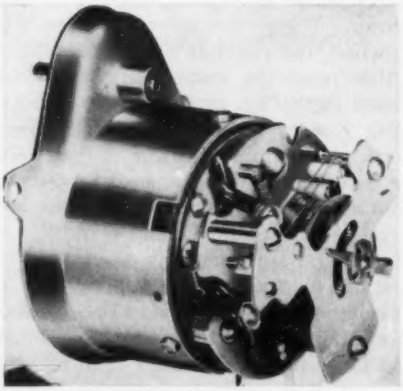

Fig 1 The chronometric governor by A. W. Haydon Co.

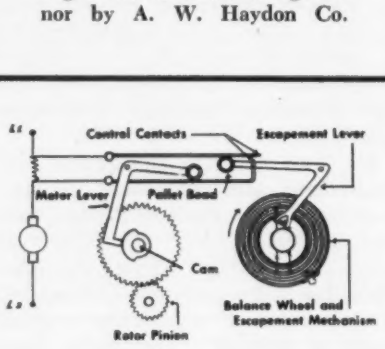

Fig 2 Principle of operation of the chronometric governor.

Its major limitation, low power transmittal, might be overcome by a dc motor provided timing was not disturbed in controling motor speed. This is the approach used in the new "chronometric governor" shown in Fig 1.

The principle of operation is shown in the schematic diagram, Fig 2. The motor is geared directly to a cam-operated lever extending between a pair of leaf spring contacts and so arranged that its motion in either direction opens the contacts. Also located between the contacts is a pallet bead, insulated by mechanical attachment to the clock escapement lever in such a manner that the clock escapement merely releases these contacts allowing them to close while the motor operated cam does the work of opening the contacts. The con-

tacts are connected directly in series with the motor so that the faster the motor tries to go, the quicker the contacts are opened; yet they close at regular intervals as released by the escapement.

Thus pulses of full line voltage are applied to the motor at regular intervals controlled by the escapement, and the duration of these pulses is determined by the travel of the motor. This results in a uniform travel of the motor during each time interval and consequently a constant rotor speed is obtained. The motor is designed to deliver maximum torque at slightly below minimum voltage under the least favorable temperature conditions. The motor, therefore, tends to overspeed but in doing so opens the governor contacts more quickly, thus shortening the duration of power pulses delivered to the motor. This results in a consequent reduction in motor speed.

Since the motor-driven cam transmits the same oscillating motion regardless of its direction of rotation, the motor is reversible. Further, when the clock balance wheel stops, it always tends to find its center position under the influence of the hairspring. Contacts always revert to a closed position when the current is turned off, and consequently the unit is reliably self-starting.

To supply power to keep the balance wheel oscillating, uniform mechanical impulses are delivered to the clock escapement through the contact springs which bear on the pallet bead, mentioned above, which is connected directly to the escapement lever. Uniformity of these mechanical pulses is assured since the contact springs are lifted a uniform distance by the oscillating motion of the cam-operated lever. Driving power for the balance wheel therefore is constant and independent of the motor speed or load and voltage variations applied to the motor.

The standard escapements are 300-beat and 900-beat types giving 150 or 450 complete oscillations per minute. The arrangement of the escapement and contact mechanism is such that the contacts are allowed to close at each half oscillation, and at this instant the escapement derives its energy from the contact springs. Thus the escapement mechanism is not called upon to perform any more work than when running free in an ordinary clock. Energy is stored in one contact spring just preceding the release of energy from the opposite spring, and the balanc wheel thus gets its impulse at a time when the contact spring is not connected to the motor.

Some typical performance figures achieved by means of this governor are: Voltage, ±20% Speed ±0.1%

SHOWN FULL SIZE

KEARFOTT SYNCHRONOUS MOTORS

High performance components, these motors find application in timing devices, recorders, or wherever constant speed is required independently of load or line voltage variations. Designed for 400 cps duty they feature homogeneous rotors and closed stator slots to eliminate magnetic pulsations and noise.

Stainless steel is used extensively in the construction of these precision motors to provide environmental protection from corrosion shock and vibration. These components will operate over the temperature range of −54°C to +125°C.

SPECIFICATIONS

Size	Part Number	Synchronous Speed	No. Phases	Pull-Out Torque
5	CJ0 0172-002	8000 rpm	2	0.10 in. oz.
8	M172-02	8000 rpm	2	0.28 in. oz.
8	CM4 0172-001	8000 rpm	3	0.31 in. oz.
11	R172-001	8000 rpm	2	0.42 in. oz.
15	T170-001	8000 rpm	2	0.78 in. oz.
18	MK 6 Mod 1	8000 rpm	3	2.2 in. oz.
23	Z1360-002	8000 rpm	3	16.0 in. oz.

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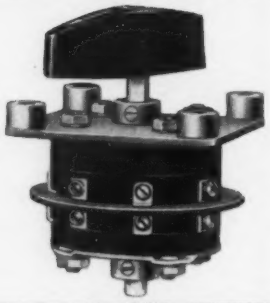
KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

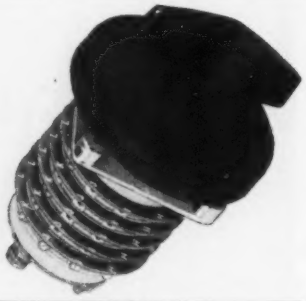
CIRCLE NO. 47 ON INQUIRY CARD

8-12-16 POSITION
ROTARY SWITCHES
for industrial and military applications

8 POSITION — TYPE JR



12 POSITION — TYPE JM



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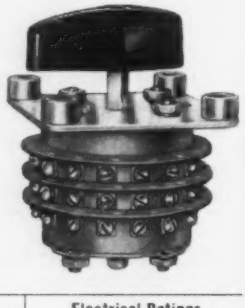

Type	Sections	Positions	Poles	Contacts	Indexing	Mounting	Electrical Ratings interrupting
JR	1 to 30	2 to 8	1 to 60	non-shorting or shorting	45°	panel	10a., 125v. a-c & 28v. d-c 5a., 240v. a-c & 125v. d-c
JM	1 to 25	2 to 12	1 to 75	non-shorting or shorting	30°	panel	7..5 amp., 125 volts a-c
JK	1 to 10	2 to 16	1 to 10	non-shorting or shorting	22½°	panel	5 amp., 125 volts a-c

These three types of ESCO rotary switches are standard items designed, manufactured, and tested to meet required environmental conditions. Special switches can be assembled, from standard parts, to meet your control requirements.

Because of the many different multi-contact assemblages possible, ESCO rotary switches can control the most complex electric circuits.

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ELECTRO SWITCH CORP.
Weymouth (Boston 88), Massachusetts

CIRCLE NO. 48 ON INQUIRY CARD

COMPONENTS DIGEST

Temperature, −65 F to +165 F
Speed ±0.3%
Vibration, 5-300 cps, 10 g max.
Speed ± 0.5%

A. W. Haydon's basic d-c timing motor for general application is a reversible unit of the wound rotor, permanent-magnet type. It differs from conventional d-c motors in that the rotor consists of a hollow aluminum (or iconel) cage with the wire wound directly on the cage. There is no iron on the rotor and therefore there are no pre-established poles to cause cogging action usually found in d-c motors near the stall condition. This motor is available in two basic series. The 5300 Series is supplied for applications where speed regulation of ±10% at rated voltage is required. Several standard windings allow operation on voltages from 4½ to 30. No load current is in the range from 25 to 100 milliamperes, as determined by the winding. The 6300 Series is a special low-current version of this motor normally supplied for operation on 45 vdc with no-load current from 5 to 10 milliamperes. This low current permits the motors to operate as integral parts of electronic circuitry, such as in the plate circuit of vacuum tubes. High impedance of the rotor windings facilitate such applications. Gear trains can be supplied with these motors for output speeds ranging from 3000 to ½ rpm. Motor speed is proportional to applied voltage and can be varied over a wide range to meet military requirements for a miniature d-c timing motor that will withstand severe environments.

A. W. Haydon also manufactures a high efficiency, high-torque d-c motor with low rotor inertia. Weighing only 2 ounces, this reversible motor has a rotor inertia of 5 gm-cm², an operating temperature range from −54 to 85°C and speed tolerance of ±10% at rated voltage. Motor speed which is proportional to applied voltage can be varied over a wide range. Standard windings are available for operation on 4½ to 30 vdc. Unique design of the rotor assembly of this unit minimizes speed changes due to applied loading and temperature variation. Eddy-currents, generated by a non-ferrous rotor assembly rotating about a stationary permanent magnet dynamically load the motor, tending to minimize speed changes due to applied loading. As the ambient temperature decreases, tendency for the motor speed to increase

due to reduced copper resistance is offset by increased eddy-current drag in the rotor cage, thus providing an appreciable degree of temperature compensation. Since there is no iron in the rotor, there are no prestabilized poles to cause cogging action usually found in d-c motors. Standard motors are available with integral gear train.

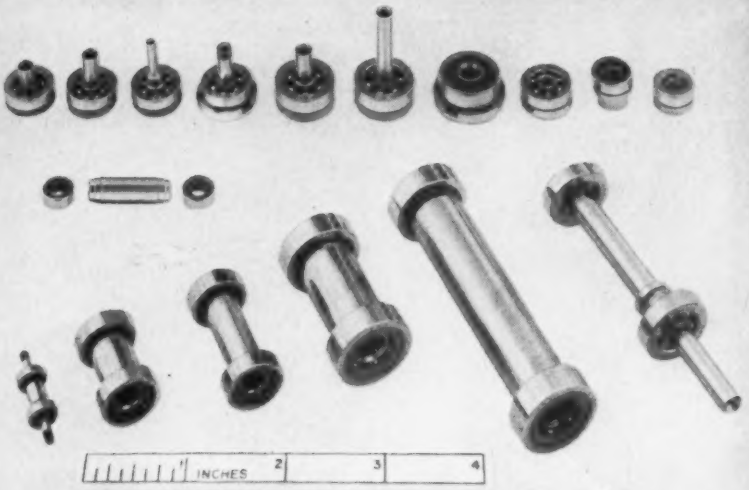
To meet exacting military requirements, A. W. Haydon makes a compact synchronous motor of the induction type for operation on 25, 50, or 60 cycles. This motor is offered in over 125 standard speeds and in 5 standard voltage ratings. Design of the motor allows direction of rotation to be established by electrical control only, eliminating need for mechanical devices with limited life. It also provides very fast starting and stopping making it possible to eliminate pre-starting and clutching in many devices such as stop clocks. Although the length of the motor is only ⅞ inch, its running torque is 30 oz-inch at 1 rpm.

For industrial, commercial and military applications where ease of reversibility is required, A. W. Haydon makes a reversible 60 cycle synchronous motor of the hysteresis type that operates on either single phase or two phase supplies. A phase shift network supplied with the motor provides one winding 90 degrees out of phase, assuring rapid starting, smooth operation and rapid reversal. For two phase operation, the phase shift network is not required, and one coil can be directly connected to each phase. Weight of the unit is 8 oz., power input is 5 watts and starting torque at 450 rpm is 0.10 oz-in.

To avoid the need for conversion to d-c timing systems in aircraft applications Haydon provides 400 cycle a-c timing motors in both standard and miniature size. The standard size is reversible and operates reliably over a temperature range of –54 to 70°C. As in the 60 cycle reversible model, a phase shift network provides one winding 90° out of phase to assure rapid starting, smooth operation and ease of reversal. Weight is 8 oz, power input 6 watts and starting and running torque 0.025 oz-inch at 3600 rpm.

The miniature 400 cycle unit is a 16 pole, reversible, synchronous hysteresis type with a phase shift network as in the larger unit and almost instantaneous starting and stopping characteristics. It also operates reliably over a temperature range from –54 to 85°C under shock and vibration conditions specified for military applications. Weight 2 oz, rotor speed 3000 rpm, power input 3 watts at 20°C, torque 0.01 oz-inch at 3000 rpm starting and running.

For more information on Haydon Motors
Write No. 358 in Box on Inquiry Card



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Highest quality, special purpose precision bearings are now available from Kearfott Division, General Precision, Inc. for military and industrial applications requiring utmost reliability, accuracy and stable performance. Over 10 years of research, testing and development have gone into the production of these outstandingly reliable, precision bearings.

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Elapsed Time Indicators

Here's some hardware that's designed for high-altitude hitch-hiking—so light (the digital read-out unit shown weighs only 1.6 ounces) and so small that they're strictly in the "no problem" category as far as load and air frame space is concerned. And in return for a lift, they give you completely reliable operating time data. There's no better way to turn "down-time" into "air-time" for critical flight systems. Dial as well as digital read-out units are available, AC or DC to suit your circuits, and they surpass the toughest military requirements easily. Write for bulletin today . . . ask for ETI-1.

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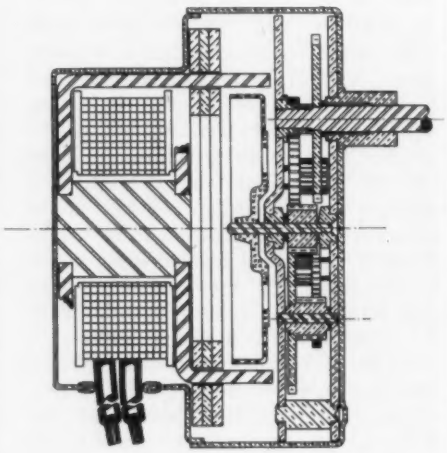
COMPONENTS DIGEST



High power and reliability in a compact design are characteristics emphasized in a wide line of synchronous timing motors, called Circle-B Motors manufactured by **Bristol Motors** of Old Saybrook, Conn. Circular in shape, with smooth, rounded corners, moisture and dust tight housings and mounting holes within the motor dimensions, they provide speeds ranging from 1800 to 1 rpm or less for a wide variety of applications. Rotor speeds are a constant 1800 rpm for 60 cycle operation. Operating temperatures are held to 65°C above ambient. All motors have high starting torques and considerably higher running torques.

With the exception of one model, all Circle B motors comprise two separate and distinct assemblies – a field unit and a gear train each independently housed and then assembled for various speed combinations. All moving parts, including the rotor, are centered in the gear train away from the warm core of the field unit. This assures long life for the special lubricant which is fed to moving parts by capillary action. This lubricating system, which does not require an oil reservoir, allows the unit to be mounted in any position. The rotor shaft is set in porous bronze graphite bearings. Gear studs are hardened steel, centerless ground and highly polished. Most gears are hobbed to insure efficiency in operation and long life. Coils are protected and tested for 2,000 volts breakdown to ground to protect the motor from the effects of high voltage surges. Wattage of Circle B standard models is 4 to 6 watts and minimum starting torque ratings range from 16 inch-oz to 50 inch-oz at 1 rpm.

Models for special applications include:

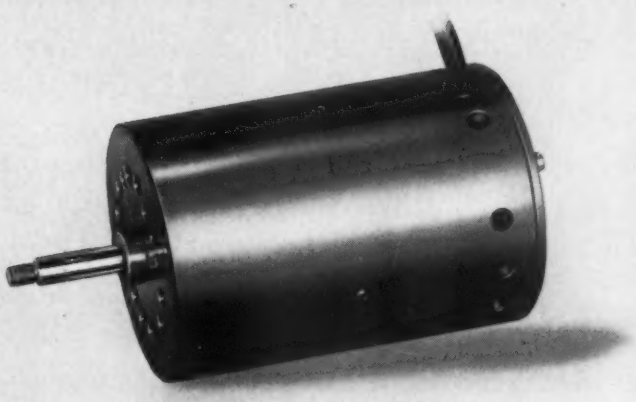
Low Speed Synchronous Motor. Designed for use in special timers or any device requiring speeds under 1/18 rpm. Especially applicable to chart drives in recording and control instruments. Speed range at 60 cycles as low as 1 revolution per month.

Dual-Speed Synchronous Motor Unit. Designed for chart drives, control devices and timers where a finite reset timer is required. Two "Circle B" motors are connected, through a special gear train, so that speed of the output shaft equals the sum of the two motor speeds. This gives a choice of three output speeds by electrical switch control of two different speed motors. Each unit is custom-made to users' requirements. Speed range 180 rpm to 1 rev per month or less. Rotation clockwise or counter-clockwise.

Internal Shift Motor. An internal mechanism engages rotor to gear train when energized and disengages gear train when de-energized, allowing train to run freely. Positive engagement of clutch in all positions is provided by the built-in solenoid. Available in speeds from 1 to 180 rpm. Output torque depends on wattage required for a given application and ranges from 9 inch ounces upward at 1 rpm.

Clutch Motor. A standard "Circle B" motor drives one of the inputs of a differential. The other input may be stopped or released by means of a solenoid-operated finger. Output of this differential connects directly to output shaft. Thus, the synchronous output shaft can be energized and de-energized instantaneously, and is disconnected from the motor gear train when not being driven. Reversible motor may be used to obtain reversible clutched output. Designed for high speed output where motor lag in starting and stopping may be objectionable. Used where a load must be driven at a synchronous speed but must be free to be set manually when the motor is de-energized. Also, used where the motor operates a load against a spring, in which case the output shaft returns to its original position when the clutch is de-energized. Typical uses are: reset timers, high-speed timers, chart drives, controls (where both a motor drive and a manual setting are required), potentiometer drives, and remote controls.

D-C Motor. Modified Bristol "Circle B" motor with the addition of a transistorized synchronous voltage inverter, externally wired to the motor. This small external inverter may be mounted in any location adjacent to or remote from the motor. Characteristics are long life (no vibrators, brushes or commutators), no radio noise (absence of vibrator eliminates high physical position), output speed independent of



AXIAL-VANE-BLOWER INDUCTION MOTORS FROM KEARFOTT

Kearfott Axial-Vane-Blower Induction Motors meet the needs of a wide range of application problems. The motors shown here represent part of the many types available for the most demanding loads and environmental conditions.

DE-20-6 | AXIAL-VANE-BLOWER INDUCTION MOTOR

This motor was designed to drive an axial-vane blower, but is adaptable to many other applications. Corrosion-resistant construction provides efficient, continuous operation in severe environments.

TYPICAL CHARACTERISTICS	Input:	200 volts, 400 cycles, 3 phase
	Output:	3.4 hp, 11,500 rpm
	Weight:	9 lbs. 6 oz.

DE-30-1 | AXIAL-VANE-BLOWER INDUCTION MOTOR

This induction motor is specifically designed to drive an axial-vane blower for coding equipment and crew compartments at altitudes up to 30,000 feet.

TYPICAL CHARACTERISTICS	Input:	200 volts, 400 cycles, 3 phase 880 watts at full load
	Output:	1¼ hp, 7,500 rpm
	Weight:	10 lbs. 2.5 oz.

C-20-37 | HIGH-PERFORMANCE, AXIAL-VANE-BLOWER MOTOR

This induction motor is a ruggedly constructed unit designed to operate without diminished performance in very severe environments. Design features include extreme speed, low noise, high efficiency and precision balance.

TYPICAL CHARACTERISTICS	Input:	200 volts, 400 cycles, 3 phase
	Output:	¾ hp, 22,300 rpm
	Weight:	3 lbs. 10 oz.

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE NO. 51 ON INQUIRY CARD

Summer Institute at Tufts University
for
TECHNICAL WRITERS AND PUBLISHERS

31 July to 11 August 1961

Director: Dr. Paul H. Flint, Professor of English
and Dean of the Graduate School of Arts and Sciences.

ESTABLISHED IN 1956 as the Workshop in Technical Writing, The Institute is given with the cooperation of leading publications specialists in the Greater Boston area, most of them senior members of the Society of Technical Writers and Publishers who have participated in the development of the Institute over several years.

THE 1961 INSTITUTE will focus particularly on analysis and discussion of the supervisory and managerial problems of publication for government and industry. In addition to the central problems of writing, editing, and production, some consideration will be given to the public-relations responsibilities of managerial personnel.

TOPICS INCLUDED

- Recruiting Writers
- In-Service Training
- Planning Text
- Editorial Procedures
- Production and Printing
- Estimating Time and Costs
- Journal Articles
- Industrial Advertising
- Specifications
- Proposals
- The Engineer's Role
- The Illustrator's Role
- The Language of the Engineer

Sessions: Two full weeks. By holding some evening meetings time is saved to keep free for personal business the afternoons of Wednesday 2 August and Friday 11 August.

Fee: $160 for two weeks; $100 for one week.

Dormitory Accommodations: For individuals, couples, and couples with children at $13 a week per person.

Meals: In the University cafeteria for Institute members and their guests at moderate prices.

Location: Nearby are the beautiful beaches of Boston's North and South Shores; Cape Cod; and the mountains of Vermont and New Hampshire. The center of Boston is twenty minutes from the campus.

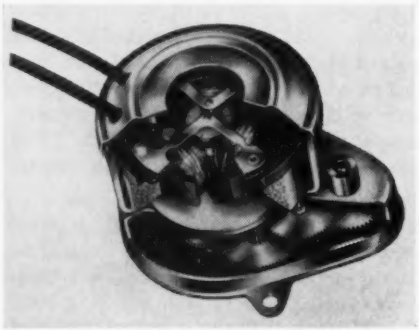
Address Inquiries to:

MRS. FLORENCE TREFETHEN, *Asst. Director*
Summer Institute for Technical Writers and Publishers
8 North Hall, Tufts University
Medford 55, Massachusetts

COMPONENTS DIGEST

vibration, shock, or physical position, no altitude problems, high reliability, 5 watts power consumption at rated voltage.

For more information on Bristol Motors
Write No. 398 in Box on Inquiry Card



Timing motor requirements where very low current drain together with high output torque, high efficiency and good speed stability are demanded, can be met with a direct current permanent magnet motor with wound rotor manufactured by **Cramer Controls Corp.** in Centerbrook, Conn. Current drain is as low as 30 milliamperes, depending on voltage, load and speed. Voltage may be from 3 to 30, torque from 0.1 to 0.6 oz-inch without gear train, speeds from 960 to 3000 rpm without gear train and from 2 rpd to 900 rpm with elliptical gear train. Low peripheral speed, and low current density of the motor brushes assure a life well in excess of 1000 hrs continuous duty.

Cramer also makes permanent magnet synchronous motors in a wide range of output speeds. Synchronous operation is reached within 2 powerline cycles, with permanent magnet breaking for instant stops. Forty-two standard output speeds are available from 1 rps to ½ rpd; numerous specials available on order. The standard models of this motor are rated at 30 oz inches torque at 1 rpm; a double-strength model is rated at 60 oz-inch at 1 rpm. Right or left rotation is available at all standard speeds. Reversible units are available at speeds of 4 rpm and faster.

For more information on Cramer Motors
Write No. 399 in Box on Inquiry Card

For specialized and demanding applications of timing motors where quality rather than cost is a primary consideration, Type K-2 motors manufactured by **Bodine Electric Co.** of Chicago, Ill. can be used to advantage. One of the smallest distributed wound motors manufactured, it provides considerably more power than clock-type motors. Since

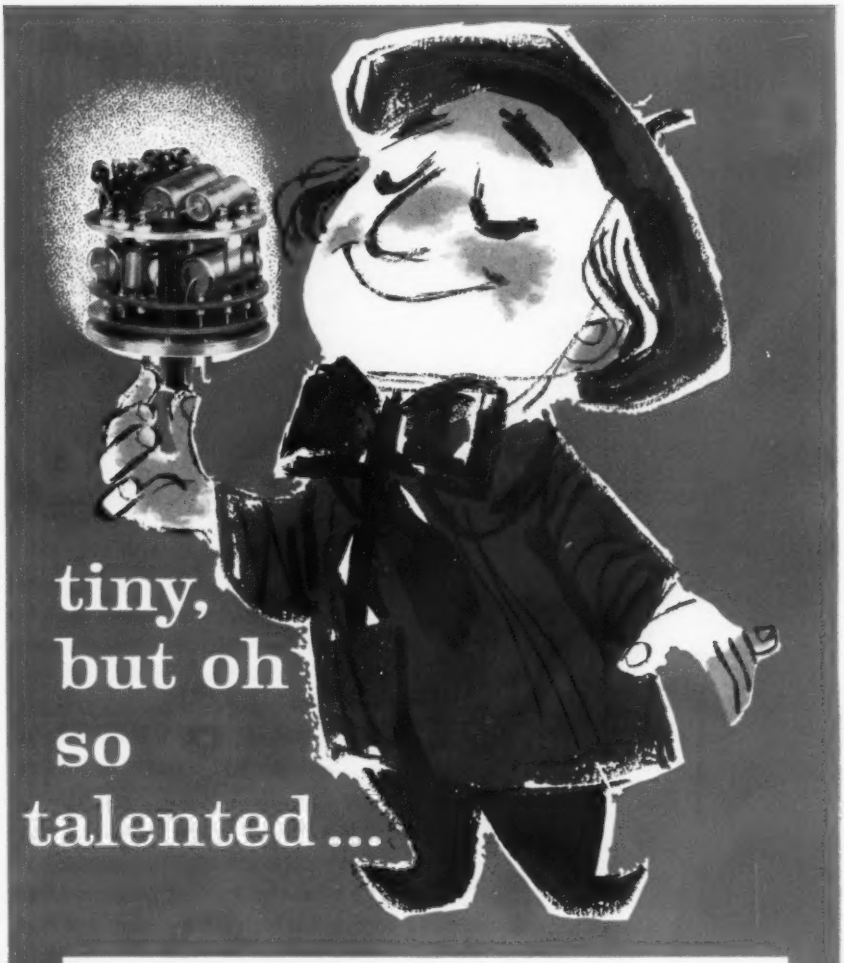
no permanent magnets are employed, performance does not decline with age. Three wire, reversible, synchronous, capacitor motors in this series are available wound for either 1800 or 3600 rpm at 60 cycles.

Torque at 1800 rpm can be 0.28, 0.37 or 0.56 in.-oz. Type K-2 motors are characterized by laminations extending through the motor. No additional frame is used to cover the edges. This construction is especially well suited for motors that must be totaly enclosed because it provides the most effective cooling with the greatest amount of magnetic iron. Ball bearings are standard for all Type K motors. The rotor is skewed to insure unusually good starting torque, eliminate dead spots and produce quiet operation. Type K-motors are available with gear trains to provide output speeds ranging from 300 to 1 rpm and torques from 1.3 to 110 oz-inches.

For more information on Bodine Motors
Write No. 403 in Box on Inquiry Card

A very wide line of 400 cycle instrument synchronous motors for drive applications requiring constant running speeds is manufactured by the **Mechatrol Division of Servomechanisms Inc.**, of Westbury, L.I., N. Y., in sizes ranging from ½ inch to 2 inches in diameter. A unique characteristic of these motors is that the bearing seats are an integral part of the stator assembly, not part of the housing. As a result the units can be assembled uncased and will operate without the housing. This characteristic is often advantageous where space, weight and cost are prime system considerations. Closed-slot stator construction and smooth rotor of these motors provide magnetic balance and eliminate electric losses associated with stator or rotor slots. Because of this construction the motors run quietly, free from cogging and vibration. They are capable of pulling high inertia loads into synchronism. Uniform flux path results in constant torque independent of rotor position. The motors have inherent self-damping of the magnetized rotor within the rotating field of the stator resulting in no hunting as the load approaches pull out torque. In some models, gearheads are supplied intergrally with the motor in a one piece housing. A versatile gearhead design offers a wide variety of gear ratios within the same basic configuration. Mechatrol list 15 basic types of standard 400 cycle synchronous motors which include 8 types of motors, 4 types of gearhead motors and 3 types of two-speed motors. The many varieties within these types provide the widest possible choice to meet the majority of applications.

For more information on Mechatrol Motors
Write No. 404 in Box on Inquiry Card



The versatile transistor servo amplifier by DIEHL

Designed for operation with any DIEHL 1, 5 or 10 watt servomotor at 60 and 400 cycle carrier frequencies, this new series of Transistor Servo Amplifiers is also capable of driving any DIEHL size 11 or 15 servomotors, or equivalent.

Superior electrical performance is typified by near-perfect linearity over a wide range of input voltage and by the absence of measurable phase shift over a 20 cps. passband.

The use of advanced packaging techniques in 2 inch diameter modules produces continuous power outputs of 6 watts in a 1⅞ inch long can or 35 watts in a 3¼ inch long can. Units are *not potted*, for accessibility and ease of maintenance; air-tight cases are filled with inert aluminum oxide particles for maximum heat transfer.

Also available is DIEHL TP 3-100 solid state power supply which accommodates either 6 or 35 watt units by means of direct plug-in.

Please write for additional information. 4178

SPECIFICATIONS

Cat. No.	TA006-0A-100
Output	Continuous; 10 watts, max. (unmounted, in free air at 25°c ambient, no heat fins) 4 watts, max. (mounted on 12 x 12 x ⅛" aluminum plate, at 71°c ambient, with ¼" heat fins)
Gain	1000 volts/volt, nominal
Input Imp.	30K minimum
Phase Shift	a) No measurable phase shift in 20 cps passband for 60 cps carrier. b) Less than 10° phase shift in 100 cps passband for 400 cps carrier.
Noise	.013 volts, input shorted
Power Req.	−28 ± 2 volts DC at .600 amp.; +9 ± 1 volts DC at .015 amp.

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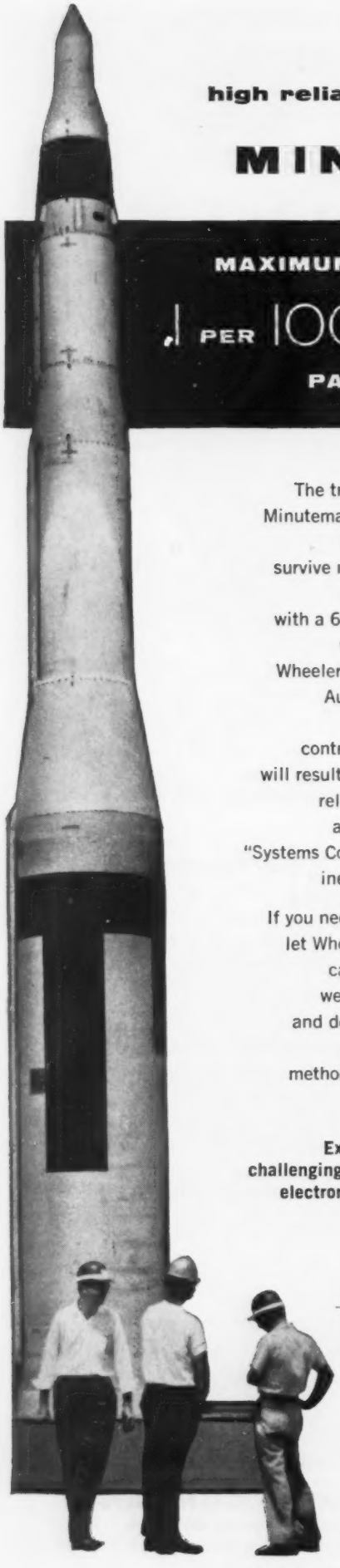

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CIRCLE NO. 53 ON INQUIRY CARD

COMPONENTS DIGEST

For precise timing applications requiring a motor in which the output shaft would always have the same mechanical relationship with respect to input phase, **Holtzer-Cabot** of Boston manufacturers a sub-fractional-horsepower polarized synchronous motor with rated torque of 0.3 oz-inch at 360 rpm, 115 volts, 60 cycles. Other characteristics are: single phase two-pole unit, a part-permanent-magnet rotor, minimum starting torque of 0.45 oz-inch and maximum no load watts of 14.

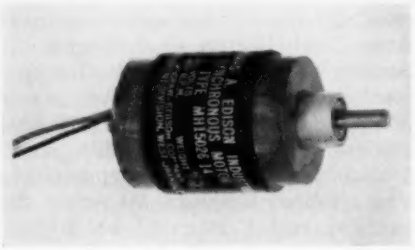
Holtzer-Cabot also manufacturers both synchronous and d-c 25-size motors, available with gear reductions from 3/1 to 3600/1, basic motor speeds from 115 to 24. The standard synchronous R-25 motor for 115 volt, 60 cycle applications, is a capacitor type with reversible rotation and is rated at 0.3 oz-inch torque at a synchronous speed of 60 rpm. It can be furnished with many variations from the standard — other voltages, odd frequencies, special windings for extra high torque and extreme temperature conditions, and special rotors for dynamic braking and quick reversing. For speeds below 900 rpm the synchronous motors are equipped with precisely hobbed spur gears and pinions. Guaranteed minimum starting and synchronous pull-in torques are 50 percent in excess of rating. This means that the motor will start and synchronize at 10 percent below rated voltage or will start and synchronize 150 percent of its rated load at rated voltage. The 25-size d-c motor is shunt wound and armature voltage may be changed for variable speed. Speed regulation is fairly constant where voltage and load remain steady.

For more information on Holtzer-Cabot Motors Write No. 405 in Box on Inquiry Card

For applications requiring from 5 to 10 times the power available in clock type miniature motors, **Hagen Manufacturing Co.** of Baraboo, Wisconsin manufactures 5 models of synchronous motors which they describe as the most powerful for their size. Coils are available for 24, 115, 230, 440 and 550 volts. Output speeds are from 1800 to 1/16 rpm. Hagen lists the following specific uses of their uni-directional motors illustrating some of their many applications: door chimes, laundry timers, depth finders, animated displays, heating controls, program clocks, fire alarm systems, integrators, time switches, chart drives, scoreboards, potentiometer drives. Models include: three uni-directional units that develop 2/3, 1 1/3 and

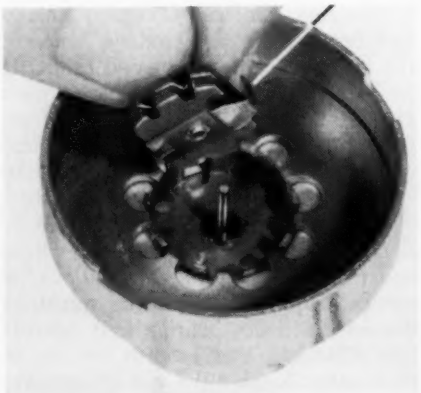
2 oz-inches torque at 60 rpm, and a reversible unit developing ⅔ oz-inches torque at 60 rpm. Both types are available with external gear train to obtain output speeds of 1/16 rpm to 1 rev per day; output shaft may be loaded up to 40 oz-inches of torque without damaging gear train.

For more information on Hagen Motors
Write No. 410 in Box on Inquiry Card



A new low-priced precision synchronous motor 1⅜" in diameter by 2⅛" long was recently announced by **Thomas A. Edison Industries, Instrument Division**, West Orange, New Jersey. Rated for 24 volts, 60 cps, the motor can be supplied with windings for other voltages up to 300 volts, 60 cps. It has a starting and synchronous torque of 0.70 inch ounces at a synchronous speed of 1800 rpm. The motor is operative over an ambient temperature range of 0°F to 140°F and its corrosion-resistant, rugged construction provides high resistances to moisture, shock and vibration. Life-time lubricated ball bearings insure long life. Its weight is 7 ounces and input power is 12.5 watts. It may be reversed by switching connections.

For more information on Edison Motors
Write No. 412 in Box on Inquiry Card



A new high torque, permanent magnet synchonous motor for program timers, computers, displays and other electromechanical devices, recently announced by **Lake City, Inc.**, of Crystal Lake, Ill. a subsidiary of **Controls Company of America,** uses an L-shaped variable pole arm to make it impossible for the motor to fail to start because of being on dead center. The small L-shaped (variable pole) arm is an inexpensive stamping that is riveted on the rotor and is not magnetized. If the poles of the rotor should ever stop on

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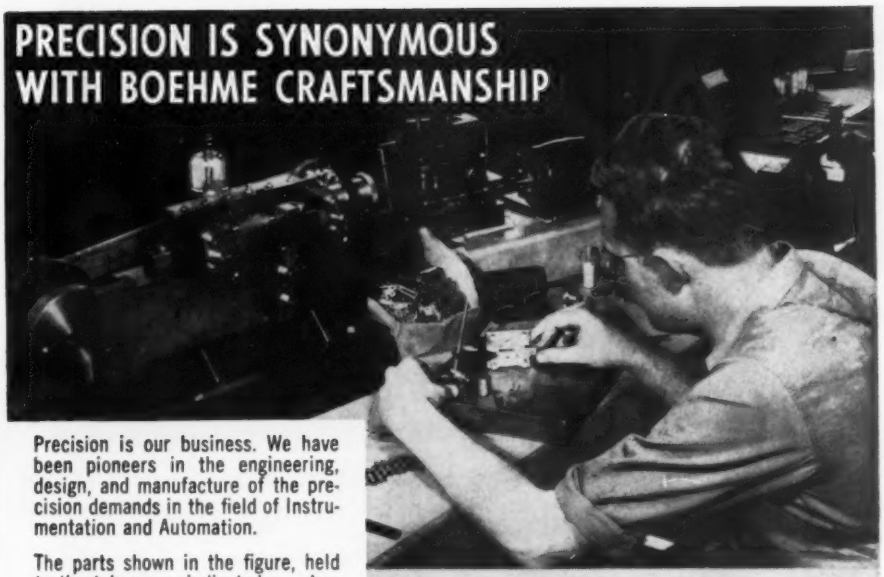

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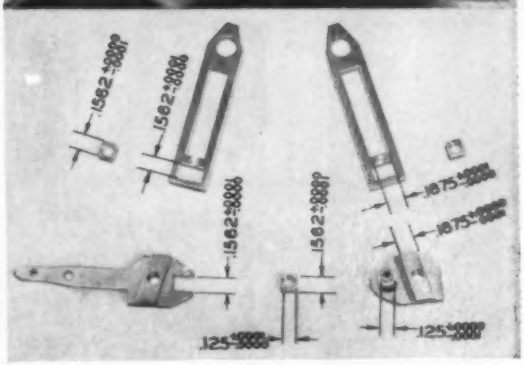

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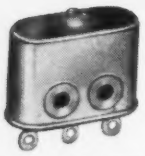
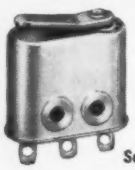
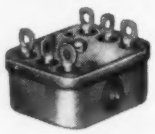


Series 6107



Series 61392



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Series 61393 Hi Temp

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1-4 pole Pushbutton and Toggle Sealed Assemblies

Series 61512

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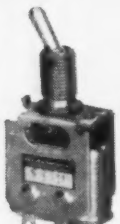
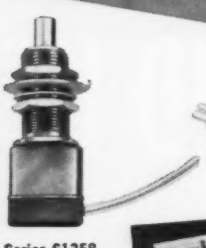
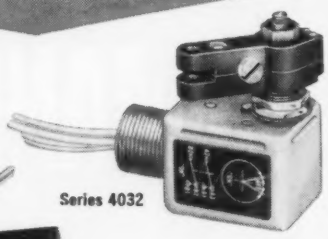


Series 6178

Sealed Plunger and Rotary limit Switches for Landing Gear and similar uses



Series 61358



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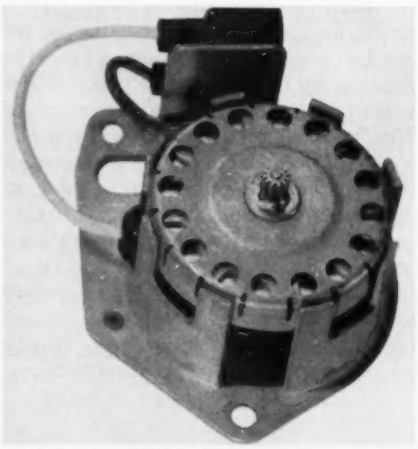
COMPONENTS DIGEST

dead center, magnetism induced in the variable pole arm by the field coil will start the rotor. This gives both permanent and alternating polarity to the rotor. Standard motor speeds available range from 10-rpm to 1/60-rpm. A positive drive clutch can be incorporated in the internal gear reduction section on most models for applications requiring a manually rotatable shaft. Available in clockwise or counterclockwise rotation, 115-volts, 60-cycles, the standard motor is rated at 20-inch ounces at 1-rpm and the high torque model is rated at 40-inch ounces at 1-rpm.

For information on Controls Co. Motors
Write No. 422 in Box on Inquiry Card



Sangamo Electric Company manufactures a small, synchronous motor of the hysteresis type developed primarily to provide an inexpensive motor with torque that increases rapidly from standstill to synchronous speed and with high pull-in and pull-out values.

A particularly important characteristic of this motor, called the Type H, is its slow speed. Since continuous operation under highly variable conditions is usually required, the lower speed of the rotor reduces bearing and lubrication difficulties and extends the life of the motor. Neither the special bearings nor the complicated oiling systems commonly used on high-speed motors are necessary. Another advantage of the slow speed motor lies in the fact that one less reduction shaft is normally required in the gear train. Synchronous speed of the Type H motor is 450 rpm. Nominal starting and pull-in torques are 20 millimeter-grams and pull-out torque is 40 millimeter-grams. Power consumption is approximately 2.5 watts for 60 cycle motors of either 120 or 240 volt rating.

For more information on Sangamo Co. Motors
Write No. 423 in Box on Inquiry Card

WORTH FILING

Control Knobs

Specially-designed slide rule and wall chart provide a finger-tip selection of more than 345 styles of control knobs. With the slide rule, you can pin-point the exact knob for your particular needs simply by setting the required specs on the sliding panel and then picking any one of the desired styles, indicated by the rule, that satisfy the specs. Permanent wall chart offers the same data as the selector plus dimensional pictures of each style knob. All control knobs meet mil specs.

Source: Raytheon Co.
Lexington, Mass.
For Your Copy Write No. 800 on Inquiry Card

Terminal Insulators

24-page bulletin includes a description of the insulator ceramic, forming techniques used, high temperature metalizing and brazing techniques and inspection. A section is also devoted to special metalized assemblies. 4-page section, "How Ceramic-to-Metal Seals Are Made," gives data for designing special ceramic and metal assemblies.

Source: Coors Porcelain Co.,
Denver, Colorado
For Your Copy Write No. 807 on Inquiry Card

Tube Shielding

Many useful curves and tables to aid in the selection of the proper shield for a particular application are presented in a 16 page booklet. A cross-index of tube type and required shield is included. Catalog section of shaft hardware describes bezels for cathode ray tubes, gear drives, shaft locks, bearings, couplings, knobs, dials, and dial locks.

Source: James Millen Mfg. Co., Inc.
Malden, Mass.
For Your Copy Write No. 808 on Inquiry Card

Measuring Rotating Power

How to measure the torque characteristics and speed of motors, gear trains, servomechanisms and potentiometers is answered in a brochure covering instruments involved with these measurements. Torque ranges from ¼ gm-cm to 200 lb-in. are discussed. Also included are formulas for computing power and efficiency, and methods of using stroboscopes and tachometers for analyzing rotating motion.

Source: Power Instruments, Inc.
Skokie, Ill.
For Your Copy Write No. 805 on Inquiry Card

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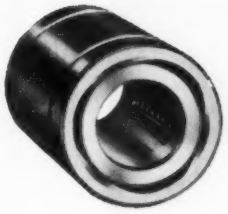
...*for* **MINIATURIZATION**



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Write No. 324 in Box on Inquiry Card

Miniature Blower

A 3.5 oz dc blower, smaller in dia. than a 50 cent piece, moves 10 cfm of air against 0.3 inches H_2O back-pressure. The tube axial unit measures in length 3¼" and operates on 27 vdc. Lower voltages may be used with different motor windings. A typical use: spot cooling of critical components in a circuit. Globe Industries, Inc., Dayton, O.

Write No. 442 in Box on Inquiry Card

Rotor Fed Transolver

In a high impedance, size 8, transolver said to be uniquely designed, the rotor, instead of the stator, serves as the primary. Included in the housing are dual output windings which may be used in signal circuits. Error variation is ±7 min checked as a control transformer with rotor excited using main stator winding red and black. John Oster Mfg. Co., Racine, Wis.

Write No. 437 in Box on Inquiry Card

Split Capacitor Motors

Two, 4- and 6-pole shaded pole and 6-pole split capacitor motors contain special moisture-proof slot and cell insulation, centrifugally die-cast rotors, and extra-large bearings with or without relubrication provisions. Smallest in the line in a 35 watt, 2-pole shaded pole motor rated at 3,000 rpm and 1/150 hp at 115v, 60 cycles. Largest is a 6-pole permanent split model rated at ⅓ hp and 1,075 rpm. All motors can be wound for 115v, 208v, or 230v operation at 50 or 60 cycles, and can be engineered for single or double shafts, thermal protectors, special mounting rings, terminals, and to fit other individual needs. Leece-Neville Co., Gainesville, Ga.

Write No. 323 in Box on Inquiry Card

General Purpose Accelerometers

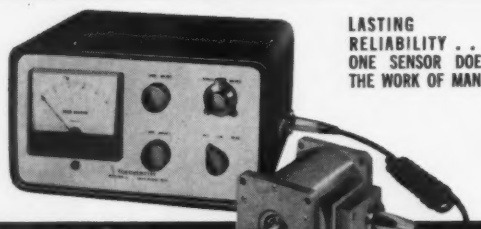
Piezoelectric accelerometers measure shock from 0.05 to 10,000 G's and vibration up to 10,000 cps with no measurable hysteresis. Units operate in ambient temperatures of —100°F to +500°F. Sensitivity: 15 mv peak per G peak. Mechanically-isolated mounting stud eliminates distortion. Linearity: ±1%; transverse sensitivity: 3%. Raytheon Co., Newton, Mass.

Write No. 498 in Box on Inquiry Card

Metal Hose

Designed for use in hydraulic, pneumatic and cryogenic lines, metal hoses embody a single longitudinal weld and smooth helical convolutions, enabling ease in cleaning. Sizes from ¼" to 1¼". Working pressure: for ¼" hose up to 4500 psi with static bend radius 1.03". Flexonics Corp., Maywood, Ill.

Write No. 504 in Box on Inquiry Card



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TORQUEMETERS
Are Factory-Calibrated to Provide Sensor Interchangeability

PRODUCTION INSPECTION LABORATORY The Model 601 Rotiform Torquemeter, with its infinitely adjustable range feature, permits observation of smaller torque increments at low torques and enables each sensor to cover a multitude of ranges. Over 200 interchangeable sensors are available with maximum torque ratings ranging from .015 oz-in to 6000 lb-in. The sensors detect torque at speeds to 65,000 rpm without physical contact with the rotating shaft. With factory calibration continuous display on the indicator is within 2% accuracy of selected full scale reading. Features include: simple compensation adjustment for ambient conditions and internal aging; sensor range changed at panel without calibration; sensor design permits either base-mounting or overhung end-mounting; solid state electronics.

ROTIFORM CO.
1509 Colorado Ave., Santa Monica, California

CIRCLE NO. 82 ON INQUIRY CARD

own your own

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Velocity Servo Amplifier

Designed to operate in conjunction with high-acceleration 2-phase ac motor-tachometer combinations, power amplifier provides in one package all the excitation, control, and feedback networks required by high-performance, high-power instrument servos. Unit suits applications requiring a motor shaft speed directly proportional to an ac control voltage (right down to zero speed). Its 90-watt capacity will accommodate a large number of motor types. Radionics, Inc., Burlington, Mass.

Write No. 460 in Box on Inquiry Card

3-Channel Tape Recorder

With neither position nor motion affecting its accuracy, an instrument magnetic tape recorder, measuring 2″ x 4″ x 5″ and weighing 31 oz (including tape) records dynamic data ranging from 100 to 5000 cycles. It records for a minimum of 1 hr at 1⅞ ips tape speed and requires ¾ watt supplied by standard low-impedance sources. With standard IRIG telemetry sub-carrier oscillator equipment, the recorder can be used for multiplexing up to 30 channels of data from dc to 100 cps. Precision Instrument Co., San Carlos, Calif.

Write No. 336 in Box on Inquiry Card

Magnetic Amplifiers

Designed to be controlled by transistors, hermetically sealed amplifiers are magnetically shielded and meet Mil-T-27A and Mil-E-5400. Power gain of magnetic structure alone is approx 40; response time approx 7.5 msec. Input and output voltages are 115v 400 cycles and have power ratings from 4 to 18 watts (conservative) to accommodate popular size 2 phase servo motors. Output is sinusoidal, amplitude variable, and phase reversible. United Transformer Corp., New York, N. Y.

Write No. 461 in Box on Inquiry Card

Synchro Transmitter

Miniature - positive, indexing - synchro transmitter package has a 100:1 gear reduction from the input shaft to the transmitter. With 48 positive detents at 72° intervals on the input shaft, the transmitter is electrically zeroed on the 5th detent. Positive stops, at the 5th detent for CCW rotation and past the 44th detent for CW rotation, withstand more than 80 in. oz. input torque. Package is 1 17/64 inches square x 2½ inches long, plus the length of the electrical connector. Complete unit weighs only 3½ ounces. Clifton Precision Prods. Co., Inc., Drexel Hill, Pa.

Write No. 300 in Box on Inquiry Card

Ten Second Resolver

Pancake resolver has a functional accuracy of 10 sec of arc and repeatability of 2 sec. Of integral bearing design, it permits direct gimbal mounting. Either the primary or secondary member can be rotated, with the other member fixed. Units are available in either beryllium or aluminum housings. Reeves Instrument Corp., Garden City, N. Y.

Write No. 457 in Box on Inquiry Card

Operational Amplifier

For general purpose closed loop use, high gain, direct coupled amplifier modules include a differential input with a high common mode rejection and low noise figure. Frequency response is flat from dc to 1000 cps. Open loop dc gain of over 1,000,000 is guaranteed. Output is capable of supplying 14 v peak at 3 ma. Power requirements are +30 v dc at 8 ma and −30 v dc at 12 ma. This amplifier module can be supplied in a package with a solid-state chopper, ac amplifier and power supply. A high voltage, high power output module capable of incorporation within the closed loop is also available. Dynamic System Electronics Corp., Scottsdale, Ariz.

Write No. 310 in Box on Inquiry Card

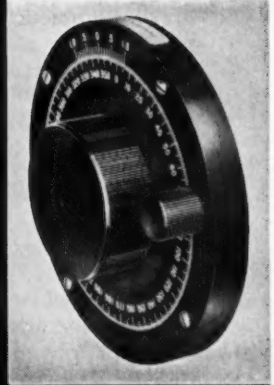
NEW design

DIAL ASSEMBLY FOR SYNCHROS AND POTS

$85 OFF-THE-SHELF DELIVERY

Just plug in your synchro, resolver, or rotary transducer and the Dial Assembly is ready for use. Designed for mounting on any panel without dis-assembly.

Specifications: Range 0° to 360°, continuous rotation. Accuracy — 0.1°. Readability — 0.1°. O.D. — 5 in. Transducer can be zeroed from front of Dial Assembly.



A Complete Technical Bulletin will be mailed to you upon request.

Theta INSTRUMENT CORPORATION

520 Victor Street • Saddle Brook, New Jersey
Hubbard 7-3508 • TWX: HKK 952-U

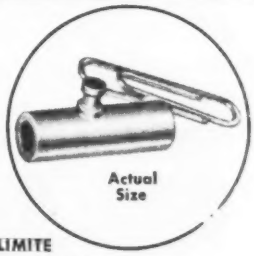
CIRCLE NO. 57 ON INQUIRY CARD

not just SMALL

this is THE SMALLEST

INERTIA SWITCH

new millimite



Actual Size

- only ¾" long x ¼" diameter
- weighs less than 1/5th of an ounce!

Light, tiny and simple, the new MILLIMITE has no springs, no bearings to wear or vary with time and temperature.

High, long-term accuracy. Meets MIL-E-5272 environmental spec.

Used for:
- Centrifugal and straight-line acceleration applications
- Shock and Vibration indication (circuit control)
- Initiating fuzes

MILLIMITE SPECIFICATIONS:

General: SPST, unidirectional, normally open
G Range: to 250 G's. Factory calibrated and sealed at any point
Accuracy: ± 10% (closer tolerances on request)
Damping: Undamped
Reset: Automatically resets when acceleration is removed
Electrical Rating: 1 amp @ 28V DC
Terminals: 1 pos. and 1 case ground
Temperature Range: − 65° to + 250° F.

Write, wire, phone for descriptive brochure EMD 5-61.

INERTIA SWITCH Inc.

311 West 43rd St., New York 36 • JUdson 6-5880

CIRCLE NO. 58 ON INQUIRY CARD

how North Atlantic's instrument servos fill the five major systems jobs . . . exactly.

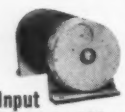
Measurement, remote display, data conversion, control, computation . . . Name the task and it's probable that the North Atlantic man can show you how to meet it precisely from NAI's comprehensive line of 3" and 2" vacuum tube and all solid state instrument servos.

Production models are available for high- and low-level ac, dc, synchro, strain gage, thermocouple, resistance bulb and other inputs. Most can be supplied with choice of pointer, counter, torque shaft or digitizer outputs. All utilize flexible design that permits any combination of input-output features to be supplied rapidly to user requirements, for both ground and airborne applications. Some are described below.

SBI-201
Single Pointer DC Ratiometer

Input
Denom. 5-50v
Num. 10 mv-100v
Accuracy
±.2 to ±.5% fs
Resolution
.1 to .2%
Response
.25 sec. fs

SBI-401
A-to D Converter



Input
10 mv to 100v dc
Accuracy
±.1% fs
Resolution
from 0.05%*
Response
from 2 sec fs*
*depending on encoder used

SBI-501
Shaft Position Repeater

Input
ac, dc or synchro
Accuracy
±.1 to ±.5% fs
Resolution
.05 to .25%
Response
7 sec. @ 15 oz-in

SBI-502
Three-Digit Counter Readout

Input
ac, dc, or synchro
Accuracy
±0.5 to .1% fs
Resolution
.02 to .05%
Response
15 sec. fs

SBI-509
Dual Scale Readout

Input
ac, dc, or synchro
Accuracy
.05 to .1% fs
Resolution
.02 to .05%
Response
6 sec. fs

If there's a critical job for an instrument servo in your system design, it will be worth your while to talk to your North Atlantic engineering representative. For his name, call or write today. Or request Catalog SFC-1 for complete data.

NORTH ATLANTIC *industries, inc.*
TERMINAL DRIVE, PLAINVIEW, L. I., NEW YORK • OVerbrook 1-8600

CIRCLE NO. 80 ON INQUIRY CARD

NEW COMPONENTS

Equipment Enclosure

Console cabinet for mounting electrical and electronic machine controls is oil and dust tight and is made of 14 gauge steel. All seams are welded and the doors and panel have neoprene gaskets. Sloping top has a hinged, removable panel on which the user can mount control buttons, switches and meters. One or two 24" x 18" sub-panels can be installed inside the console body. Vertical racks are available for mounting electronic chassis inside the body instead of sub-panels; the chassis will slide out through front door of the console. Hoffman Engineering Corp., Anoka, Ill.

Write No. 725 in Box on Inquiry Card

Single Turn AC Pot

High input and low output impedances of ac precision potentiometers substantially reduce quadrature and loading effects. Design also minimizes the chance of catastrophic failure, and provides linearity that's stable over unit's entire life. Impedance range: 1,000 to 75,000 ohms; Frequency range: 400 – 1,000 cps. Beckman Instruments, Helipot Div., Fullerton, Calif.

Write No. 532 in Box on Inquiry Card

Vibrating Reed Relay

Using tone modulated RF or single wire conductor, 1 oz vibrating reed relays remotely control up to 10 separate switching functions. Each reed controls one function through a tiny secondary relay and resistance capacitance filter. High "Q" makes this method practically interference-free. Reed units are available in 30 to 3,000 ohm coil resistances, and impedances to 5,000 ohms. W. S. Deans Co., Downey, Calif.

Write No. 531 in Box on Inquiry Card

Silicon Glass Diodes

Possessing "computer-predicted reliability," subminiature, high-speed switching diodes go through a manufacturing process that is programmed by a computer and checked throughout by a feed back system. A final analysis, based on data relating to production and testing, accompanies each batch of diodes to its purchaser. Comparison of control information with programmed standards provides a basis for predicting reliability. Princeton Electronics Corp., Princeton, N. J.

Write No. 489 in Box on Inquiry Card

CONTRACTS

Spring fever? Well, here's a couple of items to cool you off. Engineers at General Electric's Ordnance Dept., Pittsfield, Mass. will design a cryogenic accelerometer for operation at 452°F below zero. Under a $119,613 contract from NASA–George C. Marshall Space Flight Center, a development program aims at providing an accelerometer far more sensitive and accurate than any now in existence. Inertial navigation and guidance systems for land, sea, or space use, and gravity meters, precision vertical references and seismographs represent potential applications. This work complements Project Spin, a government-sponsored contract started nearly two years ago to develop a cryogenic gyro. The other "hot" cold item is from Martin Co.'s Electronic Div. at Baltimore, Md. where, under a $90,000 contract from the Air Force, engineers will investigate materials, properties and techniques required to build a superconducting, 20-microsecond delay line operating in microwave frequencies between 4 and 12 kmc. Plans call for a 15,000-foot transmission encapsulated in a 3-inch cube chamber and maintained at a temperature within four degrees of absolute zero. Dielectric losses will decrease to about a hundredth of room-temperature operation. In addition to work on the delay line, expanding cryogenic facilities at Martin's, will be used to refine hardware already developed by the company – a non-spillable dewar cryostat package for infra-red detectors and a refrigerator for cryogenic gases – and to pursue work already begun on thin films, cryogenic circuitry and bolometry.

Basic research in magnetohydrodynamics (MHD) will be extended under a new $298,410 contract awarded to the Avco-Everett Research Lab. by the Air Force Office of Scientific Research. Special attention will be given to the behavior of the magnetic field in a plasma, the radiation emitted by the plasma and the electrical conductivity of the plasma. These studies are expected to provide a better understanding of the underlying principles of MHD and to play an important role in the application of MHD to space flight and power generation and to define new areas of application. Primary research tool is a 5 foot magnetic annular shock tube (Mast). Earlier experiments in a 30 inch Mast showed the existence of interplanetary shock waves. Avco will also develop an electronic probe for analyzing MHD activity and detectors to measure the x-ray and ultraviolet radiation given off by the plasma.

BRIEFLY:

Hawk missile system: $56,894,827 to Raytheon Co. from the Army.

Infrared detectors: $1.5 million to Infrared Industries, Inc., Waltham, Mass. for the Midas Satellite program.

Computers & controls: $27 million to Eclipse-Pioneer Div. of Bendix for B-58 Hustler.

Test instrumentation: $9.5 million to Interstate Electronics Corp., for the Polaris sub. program.

Navigation systems: $8.5 million to the Sperry Marine Div. for Polaris subs.

Gas bearing gyros: $196,374 to Kearfott Div., General Precision, Inc. from the Air Force.

Missile launchers: $1,250,000 to Waterbury Mfg. Div. of Benrus Watch Co., Inc. from the Navy & Air Force.

High reliability transistors: $1,448,292 to Semiconductor Prods. Div. of Motorola, Inc. from Autometics, N.A.A., Inc.

Shillelagh missile: $5,361,619 to Aeronutronic Div., Newport Beach, Calif. from the Army.

put HEINZE in your designs

QUIET
HEINZE
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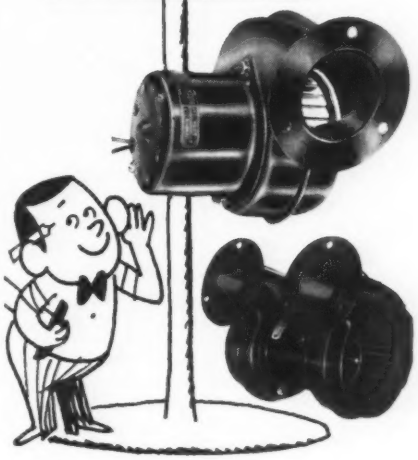
BLOWERS
AT WORK



Slow speed 4 pole shaded pole induction motor and large balanced air rotors minimize air noise to provide smooth, quiet operation. YSS Single Blower delivers 50 cfm at 1650 rpm; YSD Double Blower delivers 100 cfm. 115V, AC, 60 cycle is standard but other voltages or 50 cycle operation may be supplied. Rotation is CW or CCW. CRS housing has baked enamel finish. Variations include square outlet flange, inlet stud or tapped holes, motor vertical up or down.

YS Blowers are widely used in photographic dark rooms, laboratories, kitchens, refrigeration and air conditioning units, vending machines, for cooling electronic tubes, and similar application.

Send coupon for catalog on the complete line of Heinze Sub-Fractional Horsepower Blowers and Motors.

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Lowell, Massachusetts

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CIRCLE NO. 59 ON INQUIRY CARD

For Your Literature File

NEW CATALOGS

Most of these catalogs contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the catalogs listed on this page, enter the appropriate number of the item on the Inquiry Card.

Quick Disconnect Coupling 982

Reference to basic valving and connection principles of quick disconnect couplings summarizing the advantages and limitations of specific valving and connection concepts shows the variations or features possible with each concept, making it adaptable to almost any application. Discussed are three basic valving concepts: opposed poppet valves, tubular valve/sleeve & poppet; rotating ball valve. Also included are brief case histories of four typical connection problems. (8 pp). Aeroquip Corp., Jackson, Mich.

Rectifiers 962

Military high voltage silicon cartridge rectifiers at 1500v, 300v and 5000v PIV, provide higher current ratings, lower voltage drop and better reverse leakage characteristics than previously available types. The rectifiers, assembled in a non-metallic case, are always electrically "cold" allowing simplified mounting methods. Brochure, "Special Assemblies", gives detailed information on these rectifiers and other assemblies. (24 pp) Pacific Semiconductors, Inc., Hawthorne, Calif.

Testing Instruments 654

Three 8-page catalogs give a detailed presentation of amplifiers, square-wave and pulse generators and time-mark and sine-wave generators. Complete performance characteristics and specs are given. (24 pp). Tektronix, Inc., Beaverton, Ore.

Computer Format Recorder 652

Solid-state version of a vacuum-tube computer format recorder is described as a universal recording unit which accepts digital data from a wide variety of sources and records it on magnetic tape in digital computer format. Brochure details how the new recorder, when used in conjunction with a digital output data gathering system, automatically processes continous data into gapped computer format magnetic tape thereby eliminating the need for laborious time consuming hand coding of analog test data for computer processing. (8 pp). Epsco, Inc., Cambridge, Mass.

Circular 3-Phase Transformer 980

Brochure describes a new form of wound cut cores which produce magnetic, electrical and physical balance on all phases from no load to full load. Included in the brochure is a comparison between circular transformers and the standard E type transformer, as well as a chart showing maximum power handling of circular transformers at 400 cycles. (4 pp). Gulow Transformer Co., Carlstadt, N.J.

Precision Wirewound Resistors 978

Encapsulated precision wirewound resistors are built in standard, subminiature, and microminiature sizes in conformance with Mil-R-93A, Mil-R-93B, and Mil-R-9444. Wattage rating is full at 145°C. A unit of size 0.008 cu. inches is rated at 50 K ohms. Bulletin includes derating curves. (4 pp.) The Hanjohn Co., Inc., South El Monte, Calif.

Acceleration Switches 975

"Donner Acceleration Switches For Dynamic Accuracy" is the title of a brochure that examines the problem of meaningful accuracy in acceleration switches aboard operational missiles. Operation and variations available in the dynamically accurate acceleration switches are described. (6 pp.) Donner Scientific Co., Concord, Calif.

Miniature Relays 971

Ten amp miniature relays have exceptionally sturdy terminals and contacts for high current applications. Designed to meet the rigid requirements of Mil-R-25018, Mil-R-5757D and Mil-R-6106, the relay operates basically on dc; operation on ac can be provided by incorporating rectifiers. Glass-coated cylindrical contact actuators attached to the rotary armature assure square mating of the contact surface. (4 pp). Union Switch & Signal, Pittsburgh, Pa.

Molding Compounds 670

Containing 45 new application case histories as well as physical property data, catalog discusses a molding compound made of nylon and molybdenum disulphide. Product advantages for designers are also given. (4 pp) The Polymer Corp., Reading, Pa.

Precision Gears 959

A 128 page pocket size catalog details a complete line of stock precision gears and precision instrument clamps. Diagrams, dimensions, prices and other information is provided for rapid selection. Perfect Gear & Instrument Corp., Inglewood, Calif.

Accelerometer Frequency Calibration 656

Problems and techniques of calibrating accelerometer frequency response from 20 cps to 30 kilocycles are discussed. Performance characteristics of a high frequency calibration exciter are also included. (28 pp). B & K Instruments, Inc., Cleveland, Ohio.

Parametric Amplifiers 961

The first of 2 literature items, entitled "Parametric Amplifier Progress Report," reviews company's state-of-the-art of parametric amplifiers for application to radar and communications systems. Specs are given for L-band, S-band, C-band and X-band parametric amplifiers. The second, "Ferrite Device Data Sheets," describes and illustrates 19 ferrite units. Included are circulators, isolators, high-speed switches and modulators, available for L-band, S-band, C-band and X-band use. Hughes Aircraft Co., Culver City, Calif.

Vinyl Resins 697

Covering all aspects of formulation, processing methods and applications, a working manual analyzes vinyl plastisol and organosol technology. Text explains the distinction between plastisols and organsosols and their advantages: "They offer simple, inexpensive and versatile ways of handling high molecular weight, relatively in soluble resins." (24 pp). Union Carbide Plastics Co., New York, N. Y.

Toroids 696

A toroid application engineering bulletin contains a calibrated nomogram complete with instructions for selecting proper toroids for specific requirements. "Table of Magnetic Properties of Ferramic Bodies" and magnetic design information on specific uses for ferramic toroids are included. (4 pp). General Ceramics, Keasbey, N. J.

Time Controls 960

Industrial and military timing motors, interval timers, elapsed and time delay timers and torque controls are described in a condensed catalog. Totally enclosed timing motors are compact, rugged and dependable. Controlled lubrication meets a wide range of operating temperature requirements. These motors that mount alike, regardless of series or speed, are the basic elements of all the timing devices described. (8 pp). General Time Corp., Torrington, Conn.

Welding Equipment 956

Covering thin metal welding equipment, a catalog illustrates nine different power supplies and eight different weld heads and handpieces. Power supplies range from a 5 KVA half cycle ac unit through a 500 watt-second stored energy unit. They have short discharge times, metered controls on the stored energy models and standard production bench sizes for easy installation. Catalog also describes company's free weld evaluation service. (4 pp). Hughes Aircraft Co., Oceanside, Calif.

Stock Relays 687

Described in a catalog are: ac and dc voltage actuated relays, dc current actuated relays; general purpose relays; subminiature, miniature, small and medium size telephone type relays; plugin relays; hermetically sealed, removable dust covered and see-thru plastic enclosed relays; 10- 15- and 50 ampere small power relays; latch-in relays, and other types. (4 pp). Magnecraft Electric Co., Chicago, Ill.

INDEX TO ELECTROMECHANICAL DESIGN 1957 – 1960

COMPONENTS AND SYSTEMS DESIGN

AC ADJUSTABLE SPEED DRIVE
AC and dc motors on single shaft. Shunt field of dc motor, excited by semi-conductor-rectified ac line voltage, is controlled by rheostat to adjust speed. Rectified slip power of ac motor converted to output power in dc motor. JUNE 1958 PAGE 24

AC POWER FOR AIRCRAFT
AC electrical systems in aircraft are lighter and have lower transmission losses than dc systems with the exception of solenoid valves that operate better on dc. Here is a new solenoid valve that provides its own source of dc power when connected to an aircraft ac supply to overcome this exception. JULY 1958 PAGE 4

ADJUSTABLE GEAR REDUCER FOR CONTROL SYSTEMS
Gear reducer design permits speed ratios to be changed under full load. APRIL 1958 PAGE 4

AIR DATA COMPUTER
Balanced-force system design in analog computation. SEPT.-OCT. 1957 PAGE 42

AIR DENSITY SWITCHES
Monitoring artificial atmospheres in aircraft and missile systems. OCTOBER 1959 PAGE 8

AIRBORNE DIGITAL COMPUTER
Miniaturized system solves most navigational problems in aircraft and missiles. JUNE 1959 PAGE 42

AIRCRAFT INSTRUMENT
Two-gyro master reference. MARCH 1958 PAGE 35

AIRCRAFT PANEL POT
Used to control or adjust aircraft instruments, new ½-inch pot hermetically seals the instrument package. DECEMBER 1958 PAGE 16

ALPHANUMERIC CHARACTER GENERATION
Continuous line writing technique generates legible characters in many sizes. MAY 1960 PAGE 40

AMMONIA-TYPE MASER OSCILLATOR
Better than one part in one billion stability. APRIL 1958 PAGE 35

ANALOG COMPUTER
New component simplifies problem solving. JAN.-FEB. 1958 PAGE 7

ANALOG DECIMAL CONVERSION
Decimal readout device has adjustable zero reference. SEPTEMBER 1959 PAGE 18

ANALOG TO DIGITAL CONVERTER
Double brush design eliminates ambiguity in generating a sequential binary code. APRIL 1958 PAGE 32

ANALOG TO DIGITAL MILLIVOLTMETER
Unique servo driver tape-slidewire provides accurate digital readout. FEBRUARY 1959 PAGE 22

ANGLE OF ATTACK TRANSDUCER
Split wedge approach to angle of attack measurement. NOV.-DEC. 1957 PAGE 34

ANGLE TRANSDUCER
Direction of gravity detected photoelectrically. SEPTEMBER 1959 PAGE 34

ANNUNCIATOR SYSTEM
No moving parts: magnetic elements replace relays. JAN.-FEB. 1958 PAGE 30

APPLICATIONS OF THE HALL EFFECT
Hall multiplier serves as a wattmeter. JANUARY 1960 PAGE 14

APPLIED CRYOGENICS
Superconductivity in gyro reduces mechanical and electrical losses to "almost Zero". FEBRUARY 1960 PAGE 12

AREA ANALYZER
System simultaneously measures five dimensions, computes and records areas. JUNE 1960 PAGE 40

AUTOMATIC FAILURE LOCATION
A building block approach to reliable system maintenance. AUGUST 1960 PAGE 28

AUTOMATIC MATERIALS TESTING SYSTEM
Fast and accurate stress and strain analysis. JUNE 1960 PAGE 44

BALL BUSHING
Low friction linear instrument bearing. MARCH 1958 PAGE 16

BERNOULLI-DISK MAGNETIC MEMORY
Fluid motion principles control separation between disk and heads to obtain greater density of data storage. FEBRUARY 1960 PAGE 14

CERAMIC GYRO
Sub-Hydrodynamic suspension of a gyro in a miniature long-life bearing element accomplished. JULY 1960 PAGE 18

CODE RINGS IN REMOTE CONTROL
Translation of USSR technical report. JAN.-FEB. 1958 PAGE 73

COMMUNICATIONS ENGINEERING
Message compression for telephone. NOV.-DEC. 1957 PAGE 56

COMPONENT HOLDING AND COOLING
A sometimes overlooked factor in designing for reliability. DECEMBER 1960 PAGE 15

COMPUTER MEMORY
Air cushion separates disk from recording head. MAY 1958 PAGE 28

COMPUTER MEMORY
How to store more bits on a drum. NOV.-DEC. 1957 PAGE 50

CONTINUOUS READING METER-RELAY
Pointer trips v-shaped toggle switch. SEPTEMBER 1959 PAGE 24

CONTROLLABLE INDUCTOR CHARACTERISTICS
Ranges of performance attainable and some effective applications. MARCH 1959 PAGE 10

CONTROLLABLE INDUCTORS
Switching ideas and techniques for radio frequency circuits. SEPT.-OCT. 1957 PAGE 28

COPTOR ROTOR REGULATOR
Servo system maintains constant rotor speed. JANUARY 1959 PAGE 21

COST FACTORS IN HIGH RELIABILITY ASSURANCE COMPONENT PART PROCESSING PROGRAMS
Economics of testing the reliability of hundreds of thousands of components for thousands of hours. MARCH 1959 PAGE 4

COUPLED CAVITY STABIZATION OF KLYSTRONS
Recent improvements in techniques for stable oscillators. NOV.-DEC. 1957 PAGE 22

CURRENT CARRYING CAPACITY
A digest of information to guide systems designers in applications of switches and relays. FEBRUARY 1960 PAGE 24

CURRENT NULLING SERVOS
Some advantages of parallel summation in servo computer servos. JULY 1959 PAGE 19

CURRENT PULSE VIEWING RESISTOR
Device converts magnetron current into voltage pulses

for presentation on cathode ray tube.
MAY 1958 PAGE 26

DESIGN PROCEDURES FOR SATURATING LINEAR SERVOS
A block diagram method of analyzing and compensating a saturization servo. OCTOBER 1959 PAGE 35

DEVELOPMENT AND UTILIZATION OF REDUNDANT SYSTEMS
Failure rates of redundant systems can be thousands of times lower than for conventional systems.
SEPTEMBER 1959 PAGE 28

DIAPHRAGM-BELLOWS SEAL
Rolling diaphragm principle underlines many new piston-cylinder designs. OCTOBER 1959 PAGE 4

DIFFERENTIAL METER
Gyro design techniques develop precision instrument for monitoring or controlling current, voltage or power.
APRIL 1958 PAGE 18

DIGITAL ANALOG, HYBRID SHAFT-ANGLE INDICATOR WITH FRICTION-LESS "OPTICAL GEARING"
An invention using novel optical techniques converts shaft motion into triangular waveforms.
MAY 1958 PAGE 12

DIGITAL CLOCK
Rotary solenoids and printed circuit commutators produce time patterns for many applications.
MARCH 1958 PAGE 8

DIGITAL CONTROL AND STORAGE
Servo systems without active elements use digital shaft sensing devices. DECEMBER 1959 PAGE 26

DIGITAL ENCODER WITH MAGNETIC READOUT
Barium ferrite disc, radially spot magnetized, eliminates contacts. JANUARY 1959 PAGE 10

DIGITAL INCREMENTAL RECORDER
Unit plots directly from computer output.
OCTOBER 1960 PAGE 28

DIGITAL MAGNETIC MEMORY DRUM
True-flux-responsive readout is independent of drum speed. OCTOBER 1960 PAGE 26

DIGITAL READING OSCILLOSCOPE
Scope-output can be fed directly to digital equipment for recording or data analysis.
MARCH 1960 PAGE 34

DIGITAL READOUT PRINTER
Solenoid-lever design converts voltage pulse to lateral motion. SEPT.-OCT. 1957 PAGE 52

DIGITAL SERVOMASTERS
Stepper motors may replace ac and dc servo motors.
SEPTEMBER 1960 PAGE 40

DIGITAL SHAFT ANGLE ENCODER
Alignment cell built into this optical angle-to-digital converter makes possible angle indication accurate to better than 2.5 minutes of arc in a production model.
AUG.-SEPT. 1958 PAGE 6

DIGITAL VOLTMETER
Servo positioned potentiometer uses stepping switches in automatic range switching circuit to provide extended range of input values. JUNE 1958 PAGE 4

DC TRANSISTOR AMPLIFIER
New technique for reducing drift results in a more compact unit. NOVEMBER 1960 PAGE 28

DIRECT DRIVE TORQUE MOTORS
DC servomotors provide efficient power and allow high loop gain in stabilization and tracking systems where size, weight, power requirements and response time must be minimized and high resolution is desirable.
OCTOBER 1958 PAGE 6

DIRECT PRINTING TUBE
Development of a high definition electron gun and a unique conductive printing head in tube design makes possible high speed communication from machine to man.
MARCH 1960 PAGE 18

DIRECT READING FLOWMETER
Heated thermopile element in a flow tube provides direct reading of total mass flow of air or other gases independent of temperature and pressure variations.
JULY 1958 PAGE 10

DIRECT READING SPECTOGRAPH
Servo control aligns and stabilizes spectrum lines.
JANUARY 1959 PAGE 18

DISPLACEMENT TRANSDUCERS
High power sensitivity simplifies system design.
JUNE 1960 PAGE 30

DRY MAGNETIC-PARTICLE CLUTCHES
Principle problems in the design and selection of powder clutches. MAY 1960 PAGE 18

EDDY CURRENT CLUTCH
Electromagnetic coupling in large antenna drive control achieves smooth transmission and high acceleration with smaller motor. JANUARY 1959 PAGE 7

ELAPSED TIME INDICATOR
Novel design approach in miniaturization.
SEPT.-OCT. 1957 PAGE 18

ELAPSED TIME PROGRAMMER
Three design approaches for controlling the closing of contacts by the joint position of timing drums.
SEPTEMBER 1960 PAGE 25

ELECTRICAL CONNECTOR
More contacts in smaller space with improved molding, resins. FEBRUARY 1960 PAGE 18

ELECTRICAL CONNECTORS
Self-aligning contact pins can be inserted at any angle.
SEPTEMBEB 1960 PAGE 27

ELECTRICAL PATCH PANEL
Quick connect disconnect for missile fire control.
MAY 1959 PAGE 4

ELECTRICAL TRANSFORMER
Nested laminations as cores offer greater design flexibility. SEPTEMBER 1960 PAGE 28

ELECTROMAGNETIC ACTUATORS: PART I
Important configurations of practical torque motors described in terms of fundamental electromechanical laws.
APRIL 1960 PAGE 12

ELECTROMAGNETIC ACTUATORS: PART II
Practical torque motors in terms of fundamental electromechanical laws that may also apply to solenoids, magnetic actuators, relays and related devices.
MAY 1960 PAGE 22

ELECTROMECHANICAL BRAKE
Redesign gets more brake in less space and requires lower maintenance. New low-loss magnet produces high force at low coil power. JUNE 1958 PAGE 12

ELECTROMECHANICAL PHASE GENERATOR
Phase shifting without tubes or transistors.
SEPT.-OCT. 1957 PAGE 20

ELECTRON TUBE RELIABILITY
New heat conducting shield prolongs tube life.
JAN.-FEB. 1958 PAGE 16

ELECTRONIC CHOPPER
Switches linearly or chops voltages over a wide dynamic range. APRIL 1958 PAGE 8

ELECTRONIC DECIMAL SWITCH
By varying associated circuitry, a new switch can perform many digital functions. MARCH 1960 PAGE 10

ELECTRONIC FIBER FINENESS INDICATOR
New solution for an old problem in the textile industry.
SEPT.-OCT. 1957 PAGE 45

ELECTRO-PNEUMATIC CIRCUITS
Fast-acting air valves operate differential cylinder.
AUGUST 1960 PAGE 42

ELECTROSTATIC GENERATOR
Using compressed gas as the dielectric, French engineers

greatly multiplied the power of electrostatic generators making them practical for industrial applications of medium high voltages. NOVEMBER 1958 PAGE 24

ELECTROSURGERY
Improved design for electronic scalpel.
JAN.-FEB. 1958 PAGE 36

ENVIRONMENTAL TESTING OF BALLISTIC MISSILE RE-ENTRY VEHICLES
Acoustic noise testing, simulation of aerodynamic heating by electric arc-heated wind tunnel. Combined temperature-acceleration-vibration testing.
MARCH 1959 PAGE 28

EXPLOSION SUPPRESSORS
Automatic system snuffs out accidental blasts.
DECEMBER 1960 PAGE 32

EYETRON
A new system that converts microwave radio energy into visible light. APRIL 1958 PAGE 30

FAILURE-INDICATED MODULES
New waveform sampling device converts complex outputs of various modules to a simple dc voltage for functional analysis. DECEMBER 1959 PAGE 18

FAST WAVE PARAMETRIC AMPLIFIER
New tube removes noise from a fast wave on a stream of electrons carrying the signal, then amplifies the fast wave by externally applied alternating fields.
NOVEMBER 1958 PAGE 16

FERRITE REED SWITCH
Microsecond memory drives metallic contacts.
APRIL 1960 PAGE 16

FERROELECTRIC CONVERTER
Variation of permittivity with temperature of ferroelectric materials is used to generate high voltage power.
DECEMBER 1959 PAGE 15

FILM POT TAP
"Zero" tap width generates continuous function.
JULY 1960 PAGE 8

FLOW METER
New technique combines generation of the square root with the summing action of an all-mechanical integrator to provide direct readings of total flow.
JANUARY 1959 PAGE 4

FORCE AMPLIFIER
Mechanical unit eliminates need for electronic components in indication of process variables.
SEPTEMBER 1959 PAGE 7

FORWARD WAVE AMPLIFIER
Crossed-field design raises system efficiency.
AUGUST 1960 PAGE 21

FRACTIONAL HORSEPOWER MOTORS
Improvements reduce assembly and maintenance costs.
NOVEMBER 1958 PAGE 18

FREQUENCY DIVERSITY RADAR
Improved radar displays. MARCH 1958 PAGE 32

FUEL CELL
Smog-free power for cars. AUGUST 1960 PAGE 37

FURNACES FOR SEMICONDUCTORS
The secret of furnace design for a rapidly changing product. SEPT.-OCT. 1957 PAGE 50

FUSION-SEALED GLASS CAPACITORS
Special copper-clad leads allow true glass-to-metal seal.
JANUARY 1959 PAGE 15

GEAR PUMP
Cartridge construction with hydraulically and thermally controlled positive clearance frees pump from mechanical drag, permitting operation at high speed.
NOVEMBER 1958 PAGE 14

GEAR TRAIN ANALYZER
Constant torque actuator measures lost motion.
MARCH 1958 PAGE 36

GENEVA-DRIVE ACTUATORS
Electrically powered, mechanically positioned actuators require no moving clutches, brakes or limit switch adjustments. NOVEMBER 1958 PAGE 4

GROUND SUPPORT EQUIPMENT
Count-down monitoring of multiple power supplies.
JULY 1959 PAGE 16

GYRO PACKAGE SHAKEDOWN
System and procedure for vibration testing of turn-rate transmitter under operating conditions.
JUNE 1958 PAGE 20

HARMONIC DRIVE
A new kind of mechanical transmission.
NOV.-DEC. 1957 PAGE 28

HEAT-ELECTRICAL ENERGY CONVERSION
Practical, commercially available thermionic converters. Thermoelectric devices for high efficiency heating or cooling. New thermoelectric alloy.
OCTOBER 1960 PAGE 34

HIGH FREQUENCY CRYSTAL FILTERS
New solutions for design problems in communication, navigation and other commercial and military systems.
SEPT.-OCT. 1957 PAGE 12

HIGH SPEED PHOTOGRAPHY
100,000 magnification of time shows explosions in slow motion. APRIL 1960 PAGE 42

HIGH TEMPERATURE AIR MOTOR
Pressure relief design produces fast response.
NOV.-DEC. 1957 PAGE 32

HIGH TEMPERATURE PNEUMATIC ACTUATORS
Performance of an air motor at 1200°F.
JANUARY 1960 PAGE 18

HI-TORQUE ACTUATOR MOTOR
Converts armature vibration of an ac operated solenoid to rotary motion. MAY 1958 PAGE 10

HIGH-VOLUME TELEMETRY
Galvanometer light beams and photo-multiplier tube replace rotating wiper-arm assemblies and chopper-stabilized amplifiers in time-sharing multiplexer.
JUNE 1959 PAGE 32

HYDRAULIC PRESSURE CONTROL
Motorized actuator replaces manual adjustment of valves.
APRIL 1960 PAGE 28

HYDRAULIC VALVES
Pulse length modulation: new mode of operation.
JAN.-FEB. 1958 PAGE 12

HYPERVELOCITY PHOTOGRAPHY
Rotating mirror and rotating drum cameras accurately and reliably record position vs time of hypervelocity phenomena. DECEMBER 1958 PAGE 20

HYPSOMETER RADIOSONDE
Liquid-filled vacuum bottle measures high-altitude pressure. JANUARY 1959 PAGE 21

IMPACT OF NEW COMPONENTS ON PRODUCTION TECHNIQUES
Case histories illustrate how newness of transistorized equipment, rather than transistors themselves, causes production problems. AUGUST 1959 PAGE 6

IMPROVED MANETIC CORE DIGITAL CIRCUITRY
Better stability and increased logical gain permits use of magnetic amplifier in computers.
JANUARY 1960 PAGE 24

INCHWORM MOTOR
Magneto stricture forces actuate linear feed mechanism.
APRIL 1958 PAGE 24

INDUCTION TRANSDUCERS
Generalized approach to design of non-linear induction pots. OCTOBER 1959 PAGE 16

INERTIAL GUIDANCE WITHOUT GIMBALS
Minimizing errors produced from mounting inertial components on an unstabilized base.
NOVEMBER 1959 PAGE 18

INERTIAL GYRO TEST
Versatile torque-feedback system measures drift rate

components without the use of rate tables.
NOVEMBER 1960 PAGE 18

IN-LINE MECHANISMS
New approach to design of sub-system modules.
MAY 1958 PAGE 32

INSTALLATION HARDWARE
Multi-function chassis latches simplify computer design.
MAY 1958 PAGE 36

INSTRUMENTATION
Clamp-type AC microammeter, transistorized.
MARCH 1958 PAGE 30

INTEGRATED MAGNISTOR
New circuit technique combines the transient magnistor (high speed saturable reactor) with the permanent magnistor (saturable reactor with memory) permitting them to share a common signal element between the two control elements. DECEMBER 1958 PAGE 4

ION-MEMBRANE FUEL CELL
Solid electrolyte makes direct chemical-to-electrical energy conversion a practical power source.
JUNE 1960 PAGE 24

LEAD SCREW POT
Tiny hi-temp trimpot redesigned for reliability under extreme military environments.
DECEMBER 1958 PAGE 14

LIGHTNING ARRESTER DESIGN
Slotted laminate guides and insulates expanding spring connector designed to fasten lighting arrester to probe-type aircraft antenna. NOVEMBER 1958 PAGE 34

LINEAR POSITIONING MOTOR
New control device translates simple inputs into accurate linear motion. FEBRUARY 1960 PAGE 14

LIQUID ELECTRONIC DEVICE
Tiny circuit element outperforms tubes and transistors in special low-frequency applications.
JUNE 1959 PAGE 18

LONG LIFE FILMPOT
Progressive rather than catastrophic nature of failure in carbon film pots permits analysis of events leading to failure and reveals solution of potentiometer design problem. OCTOBER 1958 PAGE 8

LOW-COST SPEED CONTROL
Transistorized tachometer with meter relay control.
SEPTEMBER 1959 PAGE 15

LOW-COST STEPPER MOTOR
Magnetic detent reduces shock load.
JULY 1959 PAGE 4

LUMISTORS
Electrolumistors combined with photoconductors amplify electric signals. JANUARY 1959 PAGE 14

MACHINE SPEED CONTROL
New means with pneumatics.
JAN.-FEB. 1958 PAGE 20

MACHINE TOOL DRIVE
Auto-transformers and silicon rectifiers form variable speed drive. JULY 1959 PAGE 20

MACHINE TOOL POSITION CONTROL
Positioning machine tools with digital data.
NOV.-DEC. 1957 PAGE 42

MACHINE TOOL SPEED CONTROL
Faster response, easier control and higher efficiency with electronic speed drive. NOV.-DEC. 1957 PAGE 65

MAGNETIC ANALOG STORAGE
Economical digital-to-voltage conversion system.
JANUARY 1960 PAGE 22

MAGNETIC COMPUTER ELEMENT
200 flip-flops and 300 gates packaged in one-tenth cubic foot. SEPTEMBER 1959 PAGE 20

MAGNETIC CORE STORAGE SYSTEM
Standard memory building blocks make up low-cost magnetic core storage system with random access, for small computers and special purpose data handling.
NOVEMBER 1958 PAGE 32

MAGNETIC ENCODERS
Altering the magnetic state of ferrite readout cores generates a fast, reliable shaft angle-to-digital conversion.
MAY 1960 PAGE 16

MAGNETIC RECORDER FOR MISSILE TEST
Photoelectric transducers solve speed and tension control problems in tape drive. MAY 1960 PAGE 36

MAGNETIC SHAFT-POSITIONING DIGITAL ENCODER
New pick-off design removes limitation on resolution of magnetic units. SEPTEMBER 1959 PAGE 4

MAGNETIC TOGGLE RELAY
"Magnetic detenting" holds relay in either of its two normal positions dispensing with mechanical or electrical holding power. NOVEMBER 1958 PAGE 12

MASER AMPLIFIERS
New techniques reduce noise temperature to less than 10°K. MARCH 1960 PAGE 16

MATCHED MODULAR CONTROL SYSTEM
New "packaged" electromechanical control systems reduce cost and delivery time.
DECEMBER 1959 PAGE 29

MATING CLAMP
Internal cylinder clamp increases stiffness and strength of mated thin-walled sections. JUNE 1959 PAGE 4

MEASURING RANDOM SIGNALS
Voltmeter with long averaging time and high peak factor solves two major problems. AUGUST 1960 PAGE 23

MECHANICAL LOW-FREQUENCY GENERATOR
Versatile cam design generates many arbitrary waveforms. DECEMBER 1960 PAGE 16

MEDICAL ENGINEERING
Color TV in the bio lab. NOV.-DEC. 1957 PAGE 48

MEDICAL ENGINEERING
New kind of "Iron Lung" responds to automatic demand.
MAY 1958 PAGE 38

MEMORY DEVICES
Six multi-element electromechanical and electrohydraulic memory devices that may solve some of your design problems. JULY 1958 PAGE 20

METAL-CLAD SWITCHGEAR
Clean sweep re-design of 4160-volt circuit breakers.
JUNE 1960 PAGE 20

METER RELAY
A simple and inexpensive method for controlling rate and magnitude of a change in any variable that can be measured electrically. APRIL 1958 PAGE 10

MICROPHOTOGRAPHY
Stopping fast transient events with a magneto-optic lens.
APRIL 1958 PAGE 42

MILLIMICROSECOND PULSE GENERATOR
4 amp jitter-free pulses for high speed magnetic studies.
MAY 1960 PAGE 17

MINIATURE COMPONENTS MAY 1959 PAGE 10

MINIATURE CONTROL METER
No contacts at set point allows full scale indication and eliminates contact resistance, arcing and corrosion.
APRIL 1959 PAGE 4

MINIATURE GLASS TRIMMER CAPACITOR
Inexpensive "full-floating" piston design reduces size and weight and assures accurate alignment.
AUG.-SEPT. 1958 PAGE 20

MINIATURE HYDRAULIC ROTARY ACTUATORS
Two four-ounce dual-valve actuators drive airborne radar antenna. JUNE 1960 PAGE 10

MINIATURE RATE GYRO
Inside-out differential transform pickoff.
FEBRUARY 1959 PAGE 8

MINIATURE SERVOMOTORS SIMPLIFIED
Replacing the conventional laminated, slotted stator and its complex winding array with a solid magnet structure and a single bobbin-wound coil per phase reduces cost but not performance of miniature servomotors. OCTOBER 1958 PAGE 14

MSCUT GAUGE
Photocells measure length of steel sheets moving at 50,000 ft/sec on a conveyor belt and trigger mechanism to reject those over or under length. NOVEMBER 1958 PAGE 37

MISSILE AUXILIARY POWER UNITS
Electric and hydraulic power source with maximum reliability, simplicity and flexibility for missile guidance and control. JUNE 1959 PAGE 20

MISSILE COMPONENTS TESTING
From test stand to dial-a-circuit "go-no-go" simulator. MAY 1959 PAGE 7

MISSILE TRACKING
Film transport and shutter phasing designs take the bounce out of the camera. SEPT.-OCT. 1957 PAGE 20

MITE TELEPRINTER
High-speed printing without high-speed mechanical motion. APRIL 1958 PAGE 39

MOLECULAR STRUCTURED RESISTORS
Micro-module ceramic wafers have mean-time-to-failure of 100,000 hours. JUNE 1959 PAGE 30

MOTOR BRUSH HOLDERS
Constant-force brush springs minimize brush wear. SEPTEMBER 1959 PAGE 10

MULTIPOINT POTENTIOMETER RECORDER
Replacing newly designed terminal block including integral cold junction compensation adapts unit to change in thermocouple type. DECEMBER 1958 PAGE 12

N-DIGIT DECADE SWITCH
"Combination-lock" memory switch stores multiple digit numbers. OCTOBER 1960 PAGE 31

NATURAL FREQUENCY AND PHASE RELATIONS IN A DRIVEN SEISMIC SYSTEM OCTOBER 1960 PAGE 22

NEW BEARING DESIGNS
Three developments reduce friction and increase reliability in bearing applications. AUGUST 1960 PAGE 14

NEW IDEAS IN MEASUREMENT AND CONTROL
Flow measurement for computer control; New voltage-to-digital conversion technique; A torque gauge without sliprings; New thermo-drive actuator. NOVEMBER 1959 PAGE 4

A NEW LOOK AT AN OLD TECHNIQUE by Martin Kagan
NOV.-DEC. 1957 PAGE 94

NEW MINIATURE ACCELEROMETER
Unique design allows high performance of 100g shock and 20g vibration over 50-2000 cps. DECEMBER 1959 PAGE 25

NEW RECEIVING TUBE
Match-box design with mount structure locked within the envelope improves microphonism and resistance to severe vibration. JUNE 1958 PAGE 8

NEW SEMICONDUCTOR DEVICES
Radical improvements in commercial silicon transistors, temperature probes, voltage regulators and germanium power transistors. NOVEMBER 1958 PAGE 10

NEW TRANSDUCER ELEMENT
High resolution pickup operates in control systems without the use of amplification. JULY 1960 PAGE 14

NEW TRANSDUCER PRINCIPAL
High-level electrical response from minute physical motion. OCTOBER 1959 PAGE 24

NON-LINEAR ANALYSIS OF CONTROL LOOP FOR A STABILIZED MOUNT
"Torque picture" superimposed on phase plan allows prediction and control of responses. DECEMBER 1960 PAGE 26

NONLINEAR SYSTEMS
Dr. Norbert Wiener demonstrates methods of determining the contents of a "black box" so long as one knows what it going into the box and what is coming out. APRIL 1959 PAGE 26

OIL SEAL
Enclosed sealing element eliminates leakage. AUGUST 1960 PAGE 20

OPEN-LOOP PRECISION CONTROL
Precise compensation elements obtainable by new molecular engineering techniques makes re-evaluation of open-loop controls advisable. FEBRUARY 1960 PAGE 20

OSCILLATOR COMPUTER
Electromechanical resonant circuit with variable spring constant. AUGUST 1960 PAGE 12

PACKAGED DRIVES
Static devices and dc adjustable drives for machine tool systems. JUNE 1959 PAGE 40

"PANCAKE" TRANSISTOR
Wafer-thin units triple printed board capacity. AUGUST 1960 PAGE 17

PARAMETRIC AMPLIFIER
Tiny microwave device doubles range of radar systems. AUGUST 1959 PAGE 18

PERMANENT MAGNET MEMORY
Data stored by photoetched array of bar magnets on plastic cards. MARCH 1960 PAGE 28

PERMANENT MAGNET RELAY
Constant force on armature eliminates adjustments. OCTOBER 1960 PAGE 40

THE PERSISTOR
New miniature, bi-metallic printed circuit for switching and signal storage. NOV.-DEC. 1957 PAGE 36

PHASE COUPLING
Phasing synchros fast. SEPTEMBER 1959 PAGE 14

PHOTOELECTRIC DEVICE
Solid state system based on radioisotope instead of light. NOV.-DEC. 1957 PAGE 62

PHOTOELECTRIC TEMPERATURE CONTROL
Operation similar to an optical pyrometer. DECEMBER 1960 PAGE 14

PNEUMATIC-ELECTRIC PUMP CONTROL
Variable speed pulley-drives regulate pump rates. JAN.-FEB. 1958 PAGE 33

PNEUMATIC PRESSURE CONTROL
Accurate regulation by a digital servo network. OCTOBER 1960 PAGE 48

POSITIVE TEMPERATURE COEFFICIENT THERMISTORS
New thermal switches prevent over-temperature of hermetic motors. JANUARY 1959 PAGE 8

POTENTIOMETER SPECIFICATIONS FOR SEVERE ENVIRONMENTS
The importance of drawing on manufacturer's experience in writing specs for special designs. MARCH 1959 PAGE 17

POWER TRANSFORMER
New constant oil-pressure design for cooling. NOV.-DEC. 1957 PAGE 64

POWER TRANSFORMER PROTECTION
Fault-pressure relay responds to primary shock-wave produced in oil by a fault. JULY 1959 PAGE 6

POWER TRANSMISSION PROGRESS
Maintenance free magnetic clutch. Packaged electric clutch and sheave simplifies no-load starting. APRIL 1959 PAGE 12

PRECISION DC VARIABLE SPEED DRIVE
Careful brush and commutator design minimizes brush drop of feedback tachometer. FEBRUARY 1959 PAGE 24

PRECISION TORQUE TESTER
Air bearing design permits measurement of torques well below the one-tenth dyne centimeter level. MAY 1960 PAGE 32

E.M.D. INDEX

PRESSURE TRANSMITTERS
Water pressure "converted" to electircal output for indication and control. DECEMBER 1959 PAGE 24

PREVENTIVE ENGINEERING
De-icer detects symptoms of impending ice formation. SEPT.-OCT. 1957 PAGE 56

PRINTED CIRCUIT ADVANCE
Screen printing circuits on ceramic. JANUARY 1960 PAGE 20

PRINTED CIRCUIT MOTORS
Development of two-sided printed circuit boards with reliable plated through holes makes the cost, quality and engineering advantages of printed circuitry available for dc motor designs. APRIL 1959 PAGE 21

PROCESS CONTROL
Seven systems for solving control problems. APRIL 1960 PAGE 34

PROGRAM RELAYS
Moly-disulfide-filled sintered-nylon cams and ratchets withstand heavy shock and wear. NOVEMBER 1960 PAGE 38

QUADRATIC REJECTION UNIT
A low-cost, stable, electromechanical device for high gain servos. JUNE 1959 PAGE 38

RANDOM ACCESS MEMORY SYSTEM
Standard aperture ferrite memory plate is used as the storage medium in a random access memory system. DECEMBER 1958 PAGE 22

RANDOM WAVE VIBRATION SYSTEMS
New instrumentation and techniques for stimulating severe vibration environments. MARCH 1959 PAGE 22

RATE GYRO
Dashpot damper design minimizes temperature dependence. JAN.-FEB. 1958 PAGE 14

REED RELAYS
Use of short pole piece with longer moving reed permits higher operating speeds of magnetic reed switches. AUGUST 1960 PAGE 13

ROLLED MATERIAL HANDLING SYSTEM
Electromechanical equipment simplifies handling, loading, unwinding and winding of all sizes of paper, textiles, sheet metal and other rolled materials. JULY 1958 PAGE 18

SALT WATER PUMP
Bypassing two old problems: seals and corrosion. NOV.-DEC. 1957 PAGE 38

SCAN CONVERSION EQUIPMENT
TV presentation of radar information. MARCH 1958 PAGE 34

SELF-LUBRICATING BEARING
Plastic construction provides high load-carrying capacity. DECEMBER 1960 PAGE 20

SEMICONDUCTOR DEVICE
New material in tunnel diode design permits operation above 4000 MC. APRIL 1950 PAGE 25

SEMICONDUCTOR DEVICES
New developments in true-power silicon transistors, power switches, solid state multiplier and a miniature rectifier that operates red hot. APRIL 1958 PAGE 14

SEMICONDUCTOR POWER SUPPLY
Magnetic circuit regulates high-voltage dc output. SEPTEMBER 1960 PAGE 38

SENSITIVE SERVO CONTROL VALVE
Single-stage unit with two moving parts — torque motor armature and swing plate — responds rapidly to minute signals and eliminates sticking, scoring and jamming. NOVEMBER 1958 PAGE 22

SERVO CONTROL
Direct drive eliminates backlash in high performance servos. JAN.-FEB. 1958 PAGE 24

SERVO OUTPUT TRANSDUCER WITH INDEPENDENT ANGLE REFERENCE
Transducer module engages servo gear train at specified servo position and returns to specified position in response to external command signals. DECEMBER 1958 PAGE 12

SERVO WINDINGS FOR TRANSISTOR AMPLIFIER DRIVE
How to eliminate the amplifier output transformer by using the motor control winding as the transformer primary. OCTOBER 1958 PAGE 10

SERVOMOTOR APPLICATION
How to represent the operation of a servomotor mathematically in system block diagrams. OCTOBER 1958 PAGE 18

SILICON EPITAXIAL TRANSISTORS
Processing technique reduces collector resistance and switching time. DECEMBER 1960 PAGE 23

SILICON PNPN CONTOLLED SWITCH
New device achieves high gain, high speed, medium power switching beyond that possible with present-day transistors. APRIL 1959 PAGE 12

SILVER-ZINC BATTERY
Increased power with a new design. APRIL 1958 PAGE 16

SIMPLIFIED DESIGN OF COLOR PICTURE TUBES
Single-gun construction of color tubes eliminates beam convergence problems. Post deflection focusing and phosphor strip positioning further enhance color resolution. JUNE 1958 PAGE 8

600°F CONSTANT SPEED DRIVE
Mechanical traction, variable ratio transmission drive with mechanical speed, control trimmed against an electronic frequency standard powers and controls aircraft alterations in 600°F ambients. OCTOBER 1959 PAGE 30

SMALL MEGOHM POT
New resistance winding design produces 3.5 megohm resistance in a 2-inch diameter pot using 1 mil wire. DECEMBER 1958 PAGE 12

A SMALL OPTICAL TRACKER
Three circuit techniques for radiation tracking. MARCH 1958 PAGE 24

SPACE POWER SYSTEMS
Design characteristics and problem areas in some important solar power system components. SEPTEMBER 1960 PAGE 30

SPRING DRIVEN GYRO
Missile roll reference for $150. OCTOBER 1959 PAGE 14

SWITCH SELECTION AIDS
JULY 1959 PAGE 8

SYNCHROS AND RESOLVERS
Solid state trigonometric function generators and electrical two-speed synchro systems. JUNE 1960 PAGE 16

SYSTEM APPLICATIONS OF SHAFT ANGLE ENCODERS
V-scan logic design. OCTOBER 1960 PAGE 44

SYSTEMS PACKAGING
Greater damping of resonant vibrations achieved without the use of vibration isolators. MARCH 1960 PAGE 22

TACTILE COMMUNICATIONS SYSTEMS FOR AIRCRAFT
Coded vibratory stimuli overcome communications problems caused by human reaction-time delay and visual and aural sense saturation. JULY 1958 PAGE 14

TAUT BAND SUSPENSION SYSTEM FOR SWITCHBOARD INSTRUMENTS
New design, dispensing with pivots and bearings, does away with rolling and sliding friction. JULY 1958 PAGE 9

TELEMETRY
Precision voltage monitor for accurate data transmission.
MARCH 1958 PAGE 12

THE DIRECT APPROACH
Electronic sensing replaces conventional limit switch.
AUGUST 1959 PAGE 18

THE TRANSISTOR REGULATED POWER SUPPLY AS A FEEDBACK CONTROL SYSTEM
How to design transistorized power supplies that function accurately under severe conditions.
JUNE 1958 PAGE 14

THERMOELECTRIC MODULES
Cooling below ambient temperatures significantly reduces component failure. APRIL 1960 PAGE 26

THERMO-ELECTRON ENGINE
Atomic heat converted to electricity; no moving parts.
APRIL 1958 PAGE 27

THREE-PHASE STATIC INVERTER
Output voltage reaches full value in 100 microseconds.
MAY 1958 PAGE 20

3-D VIEWING
Lenticular screen simulate c-d images without the aid of optical devices. APRIL 1958 PAGE 36

TINY SAMPLING SWITCH
Development of contact pins with exceptional durability with reduced noise. JULY 1958 PAGE 6

TORQUE-FREE BEARING ASSEMBLY
Electromagnetic oscillation of outer bearing ring reduces both starting and running friction below 25 dyne centimeters — practically an irreducible minimum.
AUG.-SEPT. 1958 PAGE 12

TRAVELING WAVE AMPLIFIER
Solid state design achieves high amplification without self-oscillation. APRIL 1960 PAGE 26

TRIMMER POTS
So small — 16 to the square inch, 500 per lb.
APRIL 1958 PAGE 12

"TRUE MASS" FLOWMETER
Novel technique uses small gyro to totalize flow.
JULY 1959 PAGE 18

TURBINE FLOWMETER PICKOFF
AC carrier transducer with high frequency signal output.
FEBRUARY 1959 PAGE 14

TWISTOR SHIFT REGISTER
Single magnetic wire stores pulses when subjected to magnetizing field. JANUARY 1959 PAGE 8

2-D TRACER SYSTEM
Electromechanically controlled system will follow any contour around a 360° path at constant speed.
JANUARY 1960 PAGE 26

TWO-INCH ATTITUDE INDICATOR
Standby indicating system virtually equals primary system. JANUARY 1960 PAGE 26

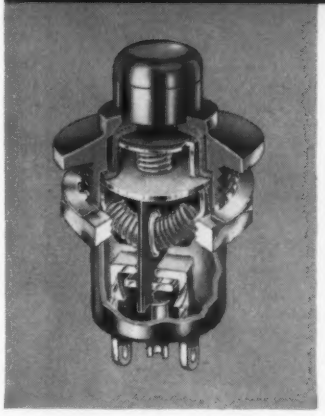
TW-SCOPE — TV INSPECTION SYSTEM
Traveling wave scope in closed circuit TV solves problem of inspecting waveforms of high speed switching transistors with rise-time of millimicroseconds and switching of about 10 volts.
NOVEMBER 1958 PAGE 36

ULTRASONIC DELAY LINES
Multicomponent glass materials reduce temperature dependence. MARCH 1960 PAGE 14

VARIABLE REACTANCE MICROWAVE AMPLIFIERS
Semiconductor diodes whose capacitance varies with voltage applied from high pump signal provide time varying capacitance and supply energy for amplification with reduced noise. JULY 1958 PAGE 6

VARIABLE SPEED DRIVE
Armature control of dc motor using silicon controlled rectifiers. SEPTEMBER 1960 PAGE 14

ELECTROMECHANICAL COMPONENTS
PRECISION MADE FOR MAXIMUM RELIABILITY



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Sinusoidal, toggle spring design ensures positive, tease-proof snap action... minimum arcing and contact wear. Heavy coin silver contacts for long life and low resistance. Color coded buttons. Wide choice of housings, mountings and contact arrangements.

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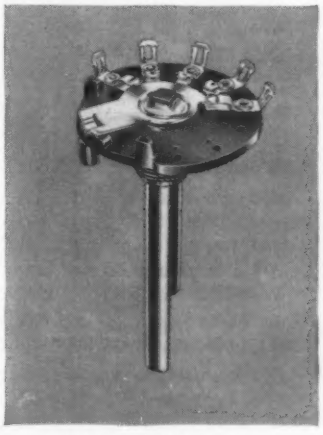

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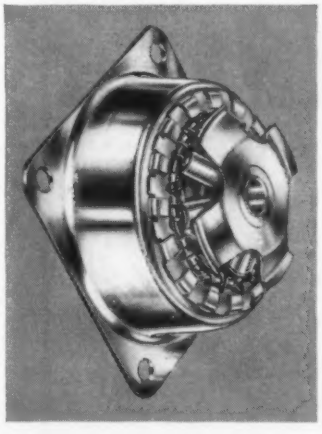

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Outperform rubber (absorb shock from all directions) outlast rubber (unaffected by dirt, grit, oils, corrosive atmospheres). Available in plate and cup types for loads up to 35 lbs. per mount.

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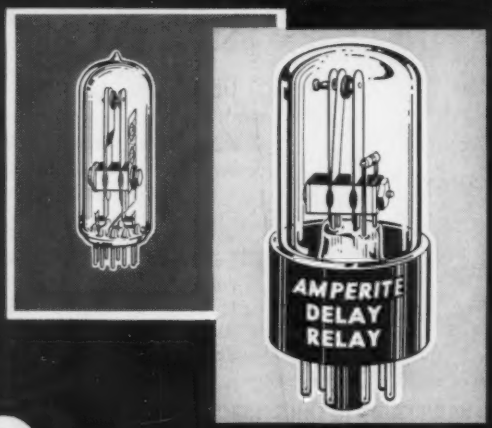
AMPERITE

Thermostatic DELAY RELAYS



Only a glass seal offers true hermetic sealing ..assuring maximum stability and life!

Delays: 2 to 180 seconds . . . Actuated by a heater, they operate on A.C., D.C., or Pulsating Current . . . Being **hermetically sealed,** they are not affected by altitude, moisture, or climate changes . . . **SPST only**—normally open or normally closed . . . Compensated for ambient temperature changes from —55° to +80° C. . . . Heaters consume approximately 2 W. and may be operated continuously . . . The units are **rugged, explosion-proof, long-lived,** and—**inexpensive!**

TYPES: Standard Radio Octal, and 9-Pin Miniature . . . **List Price, $4.00.** Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

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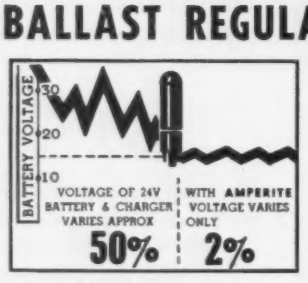

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E.M.D. INDEX

VERNIER POT
10-turn resolution in 2-turn size.
FEBRUARY 1959 PAGE 21

VIBRATION TESTING
Electrohydraulic systems combine high force and long strokes. APRIL 1960 PAGE 31

VIDEO RECORDER CAPTURES RADAR TRACKING SIGNALS
New recording method permits higher frequency radar signals to be packed on magnetic tape.
NOVEMBER 1959 PAGE 17

VOLTAGE TUNABLE MAGNETRON
New smaller VTM packages are ½ order of magnitude improvement in power output and efficiency.
JUNE 1959 PAGE 16

WATT-HOUR METERS
Magnetic thrust bearing, key to friction-free design.
AUGUST 1960 PAGE 25

WIRE TAP TERMINALS
Flute design speeds assembly.
JULY 1959 PAGE 10

XENON-FLASHLAMP SENSITOMETER
Electronic flash supplies remarkably constant light source that approximates daylight quality without use of filters and allows study of film and development characteristics in the range of high speed photography.
AUG.-SEPT. 1958 PAGE 24

ZENER CONSTANT CURRENT SOURCE
Solid state circuiting replaces standard cells and standardization mechanisms in potentiometric instruments.
JANUARY 1959 PAGE 12

ZERO LENGTH UNBONDED STRAIN GAGE
New configuration simplifies transducer design.
FEBRUARY 1959 PAGE 18

COMPONENTS DIGEST

A-C INSTRUMENT SERVOMOTORS
New kind of technical reporting presents key facts on commercially available electromechanical components. This first Digest covers ac instrument servomotors with standard synchromount construction and general performance characteristics.
OCTOBER 1958 PAGE 33

ANALOG-DIGITAL CONVERTERS: PART I
Classification; shaft position encoders; theory of V-scanning; self-contained logic elements; multispeed binary coder; coupling coders to other components.
JUNE 1959 PAGE 65

ANALOG-DIGITAL CONVERTERS: PART II
Optical shaft encoders; Voltage encoders.
JULY 1959 PAGE 47

ANALOG-DIGITAL CONVERTERS: PART III
Performance charactertistics of commercially available analog-digital converters. Buyer's guide to analog-digital converter manufacturers. AUGUST 1959 PAGE 27

AUDIO POWER AMPLIFIERS
Part 1: Introduction
Continuous and discontinuous amplifiers, magnetic and thyratron amplifiers, transistor and vacuum tube amplifiers.
Part 2: Transistor Amplifiers
Basic fundamentals, biasing, leakage current, thermal stability, thermal run-away, nonlinear biasing, thermal resistance, operating range, efficiency and distortion, feedback, frequency response, noise.
JANUARY 1960 PAGE 53

AUDIO POWER AMPLIFIERS: PART III
Magnetic Amplifiers
General considerations; equivalent circuit; saturable cores; a simple saturable reactor; parallel connected re-

actor circuit; feedback; self-saturation; fast response.
APRIL 1960 PAGE 61

AUDIO POWER AMPLIFIERS: PART IIIB
SEPTEMBER 1960 PAGE 56

BASIC CONCEPTS FOR AC SERVOMOTOR APPLICATIONS
OCTOBER 1958 PAGE 34

BUYERS' GUIDE FOR INSTRUMENT SERVOMOTORS
DECEMBER 1958 PAGE 60

CHARACTERISTICS OF CARBON FILM PRECISION POTENTIOMETERS
DECEMBER 1958 PAGE 38

CHARACTERISTICS OF METAL FILM PRECISION POTENTIOMETERS
DECEMBER 1958 PAGE 40

CHARACTERISTICS OF TRIMMING POTENTIOMETERS
DECEMBER 1958 PAGE 42

CONNECTORS AND FASTENERS: Part I
Military Connectors-multiple contact, design and selection factors, specifications, environmental factors, buyer's guide for connectors, quick operating fasteners, selection factors, standards, buyer's guide for fasteners.
MAY 1959 PAGE 6

CONNECTORS: Part II
RF connectors; Printed circuit connectors, Umbilical connectors. JULY 1959 PAGE 33

DIGITAL VOLTMETERS
Sampling frequency, basic converter types, converter bandwidth, selection factors, commercial equipment.
DECEMBER 1960 PAGE 58

DC REGULATED POWER SUPPLIES
Several considerations, open loop and closed loop regulation; types of supplies, specifications, summary data charts, new power supplies.
JULY 1960 PAGE 42

ELECTRICAL INSULATION
The insulation design problem, insulation characteristics, hi-pot testing, selection of specific insulations, conference papers on applications, new insulations for electromechanical designs, new insulation literature.
MAY 1960 PAGE 65

ELECTRICAL RESOLVERS
Fundamentals of resolver performance; the ideal resolver; nonideal aspects of performance; manufacturing errors; application factors; equivalent circuit; compensation circuits; non-booster compensation; resistance-type resolvers; sine-cosine generators.
FEBRUARY 1960 PAGE 49

ELECTROMAGNETIC AND POTENTIOMETER TRANSDUCERS: PART I
1. Resistive & magnetic pickoffs. 2. Magnetic transducers, basic theory. 3. Transducer equivalent circuits. 4. Effect of small circuit changes on performance. 5. Temperature compensation of output magnitude. 6. Inductive pickoffs. 7. Synchros. 8. Electrical resolvers. 9. Induction potentiometers. 10. Differential transformers. FEBRUARY 1959 PAGE 41

ELECTROMAGNETIC AND POTENTIOMETER TRANSDUCERS: PART II
Synchrotels, Inductosyns, Magnesyns, Microsyns.
MARCH 1959 PAGE 33

ELECTROMAGNETIC AND POTENTIOMETER TRANSDUCERS: PART III
Very low torque pots,, accelerometers and pressure pickups, summary of manufacturers' data, buyer's guide for transducers. MAY 1959 PAGE 35

ELECTROMECHANICAL SWITCHES: PART I
Selection Procedures, selection factors, environmental factors, contacts, contact resistance, types of switches, rotary selector switches, printed circuit switches.
AUGUST 1959 PAGE 35

ELECTROMECHANICAL SWITCHES: PART II
Precision switches, heavy duty limit switches, pressure switches, thermal switches, motor protection, miscellaneous switch types, mercury switches, crossbar switches. SEPTEMBER 1959 PAGE 57

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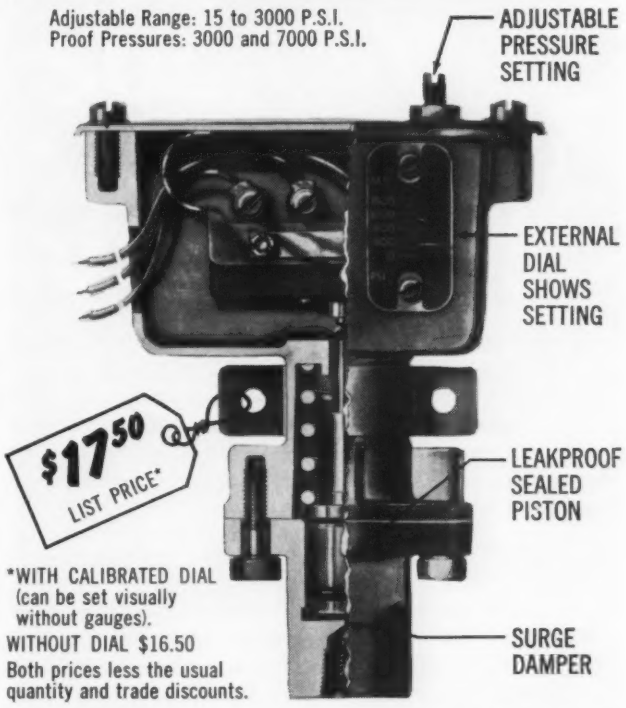

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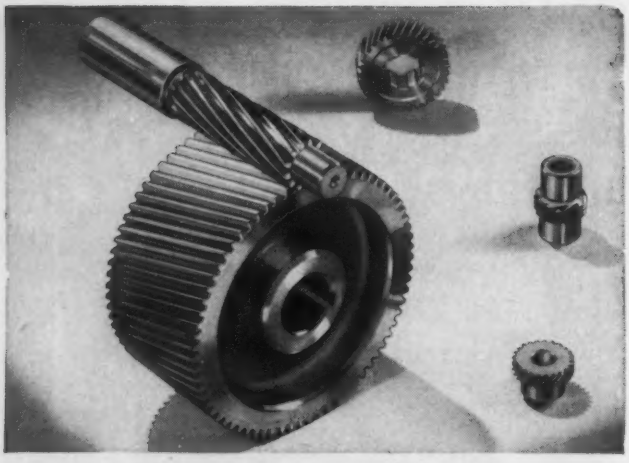

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E.M.D. INDEX

ELECTROMECHANICAL SWITCHES: PART III
Coaxial Switches: Application and selection factors; design features; commercially available units; modifications of standard types.
NOVEMBER 1959 PAGE 63

ENVIRONMENTAL TESTING: PART I
Qualification testing, reliability, environmental test laboratories, military specifications, random vibration testing, chart of environmental test specifications, description of environmental tests, acoustic noise testing, radiation effects. MARCH 1959 PAGE 43

ENVIRONMENTAL TESTING: PART II
Radio interference; test chambers; vibration and acoustic noise; buyer's guide to environmental test equipment and laboratories. JUNE 1959 PAGE 49

FIGURES OF MERIT OF SERVOMOTORS
OCTOBER 1958 PAGE 46

FRACTIONAL HORSEPOWER MOTORS
Induction motor characteristics, power supply requirements, principles of induction motors, characteristics determined from equivalent circuit, measuring the equivalent circuit, single phase machines, unbalanced operation, dynamic load characteristic, application factors, variable frequency motors, motors for blower applications, efficiency of high-slip units, environmental factors, ordering a motor, motor efficiency.
SEPTEMBER 1959 PAGE 51

FUNDAMENTAL FORMUAS FOR LINEAR SERVOMOTORS
OCTOBER 1958 PAGE 46

MATERIALS AND TECHNIQUES FOR HIGH-TEMPERATURE COMPONENTS
Evaluating and selecting insulations & insulating materials; conductors; soldered connections; ball bearings for high temperatures; lubrication application factors; high speed bearings; fits & tolerances; needle bearings; materials for rings; balls, retainers, shields & seals.
DECEMBER 1959 PAGE 55

MATERIALS AND TECHNIQUES FOR HIGH-TEMPERATURE COMPONENTS
(Cont'd from December issue). Magnetic materials.
JANUARY 1960 PAGE 48

MINIATURE MAGNETIC CLUTCHES & BRAKES
Clutch applications; principles of operation; application factors; the clutch as an actuator; miscellaneous considerations. MARCH 1960 PAGE 49

MINIATURE SERVO PACKAGES
Standard packages, basic components, common variations, construction features, alternative construction, indicator-type devices, servometers, servo-amplifiers, gearheads, synchros, pots, magnetic clutches, additional elements, buying a package. JUNE 1960 PAGE 70

NON LINEAR POTENTIOMETERS
DECEMBER 1958 PAGE 27

PERFORMANCE FACTORS OF PRECISION WIREWOUND POTENTIOMETERS
DECEMBER 1958 PAGE 28

POTENTIOMETERS
Part II: High-temperature pots.
Intermediate temperature units, 300°–500°C units.
JANUARY 1960 PAGE 41

POTENTIOMETER STANDARDS — DEFINITIONS AND REQUIREMENTS
DECEMBER 1958 PAGE 46

PRECISION POTENTIOMETERS
DECEMBER 1958 PAGE 24

RESOLVER TABLE — ELECTRICAL RESOLVERS: PART II
OCTOBER 1960 PAGE 76

SENSITIVE RELAYS
Basic relay parts. Magnetic circuit fundamentals. AC vs. dc relays. Polarized relays. Effect of miniaturization. Contact arrangements. Relay coils. Hi-speed operation. Low-speed operation. Construction features. Environmental requirements. Relay contacts. Dry circuits. Re-

lay definitions. Charts of sensitive relay characteristics.
APRIL 1959 PAGE 45

SERVOMOTOR STANDARDS
Standard definitions proposed by SAE in APR 497.
Tentative SAE standard dimensions.
Tentative SAE standard specifications.
OCTOBER 1958 PAGE 41

SERVOVALVES
Classification and description of common types, advantages and disadvantages and typical applications of valve-controlled systems, servo valve terminology, dynamic characteristics and transfer functions, selection factors, nomographs for selecting optimum servo valve, description and performance characteristics of commercially available units. NOVEMBER 1960 PAGE 55

STATUS OF PRECISION POTENTIOMETERS
DECEMBER 1958 PAGE 51

SUMMARY CHARTS
Mechanical and electrical performance summary charts for commercial instrument servomotors.
OCTOBER 1958 PAGE 44

SUMMARY OF ELECTRICAL AND MECHANICAL CHARACTERISTICS OF PRECISION WIRE-WOUND POTENTIOMETERS
DECEMBER 1958 PAGE 54

TYPES OF AC INSTRUMENT SERVOMOTORS
OCTOBER 1958 PAGE 37

DESIGN TIME SAVERS

ANALOG COMPUTER — DESIGN OF MAGNETIC AMPLIFIERS
Time saving techniques for simultaneously solving the several equations involved in magnetic amplifier design.
DECEMBER 1959 PAGE 36

CALCULATION OF NATURAL FREQUENCIES OF DAMPED SYSTEMS
An easy method of modifying solutions for the motion of an undamped system to account for damping.
JANUARY 1960 PAGE 36

DESIGNING FOR SPECIFIED FIELD DISTRIBUTION IN MAGNETIC CIRCUIT AIR CAPS
A simplified approach to field density problems.
APRIL 1960 PAGE 56

DOUBLE MASS-SPRING SYSTEMS
Useful transmissibility curves for designing high speed track carriages. JUNE 1960 PAGE 67

DYNAMIC LOAD CHARACTERISTIC OF ELECTRIC MOTORS
A new way of selecting motors.
JAN.-FEB. 1958 PAGE 56

EVALUATING INSULATED SPLICES
Splice performance is rated quantitatively on how the splice compares dimensionally, mechanically and electrically to the length of cable it replaces.
JUNE 1958 PAGE 44

FASTENING DESIGNS
Over 100 fastening methods for speed, inserts, safety, simplicity, appearance, adjustment and sealing.
MAY 1960 PAGE 46

FASTENING DESIGN — PART II
Platings, finishes, head terminology and point terminology associated with the selection and application of fasteners. AUGUST 1960 PAGE 56

14-CHANNEL INSTRUMENTATION TAPE RECORDER
Differential capstan drive holds magnetic tape on constant tension against heads eliminating variations that cause wow and flutter. AUG.-SEPT. 1960 PAGE 30

GENERALIZED DYNAMIC LOAD CHARACTERISTIC
Curves show, directly, available power from a motor and the optimum gear ratio for any load acceleration to velocity ratio. SEPTEMBER 1959 PAGE 44

HOW TO SPECIFY SOLENOID VALVES
A check-list of electrical and mechanical application requirements that affect a valve manufacturer's proposals and recommendations for a specific design.
JANUARY 1959 PAGE 40

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E.M.D. INDEX

MOMENTS OF INERTIA OF A PARABOLOIDAL SHELL
Solution of the chief problem in the analysis of a radar antenna drive for a parabolic reflector.
NOVEMBER 1959 PAGE 45

PHASE IN LEAD LAG NETWORKS
Simple curves provide quick solution to lead, lag problems. JULY 1960 PAGE 33

PLATINUM RESISTANCE THERMOMETERS
All the information you need to use platinum resistance thermometers in a variety of bridge circuits and control systems. JULY 1958 PAGE 40

PORCELAIN TO ALUMINUM SEAL
Mechanically reliable, vacuum-tight seals result from bringing high-purity molten aluminum into contact with alumina-silica ceramics under carefully controlled temperature and temperature-change conditions.
AUG.-SEPT. 1958 PAGE 32

PREDICTING RESPONSE TO MODULATED INPUTS FROM RESPONSE TO SINE WAVE INPUTS
A simple method of determining a component's frequency response. OCTOBER 1959 PAGE 48

PRECISION COMPRESSION SPRING DESIGN
A logical step-by-step procedure that eminates tedious calculation. SEPT.-OCT. 1957 PAGE 82

RELIABILITY
Three simple graphs — and you can evaluate most equipment reliability. JAN.-FEB. 1958 PAGE 61

RELIABILITY STRESS ANALYSIS FOR ROTARY ELECTRICAL DEVICES
How to predict the reliability of motors, blowers, generators, dynamotors, synchros and resolvers.
OCTOBER 1958 PAGE 24

RELIABILITY TESTING
A specific technique for determining if your equipment is adequately engineered. MARCH 1958 PAGE 50

RIGHT BATTERY FOR THE JOB
Performance charts and selection criteria for batteries.
MAY 1958 PAGE 46

SELECTION OF PILOT LIGHTS BY LAMP TYPE
DECEMBER 1960 PAGE 38

SERVO DESIGN CHARTS
Bandwidth for a pair of complex poles.
MAY 1959 PAGE 24

SERVO DESIGN CHARTS
This issue starts a series of timsaving servo charts, presenting important design data in compact and easy-to-read form, with uniform notation. Now you can solve by inspection many problems that formerly required tedious calculation by trial and error.
JULY 1958 PAGE 38

SERVO DESIGN CHARTS
Second in series of charts for solution of servo design problems by inspection. NOVEMBER 1958 PAGE 44

SPECIFYING AN INSTRUMENT SERVOMECHANISM
Black box treatment of servomechanisms considering over-all performance requirements.
NOVEMBER 1959 PAGE 32

SPRINGS: HOW TO DEAL WITH HIGH TEMPERATURES
By proper choice of materials and by certain design changes and processing modifications you can now obtain satisfactory spring performance under high-temperature operating conditions. AUG.-SEPT. 1958 PAGE 38

STANDARDIZING AND MEASURING PRECISION TRANSDUCERS
How to design trimming circuits to standardize transducers and test sets to measure their performance.
FEBRUARY 1959 PAGE 36

STRESS ANALYSIS IN FINNED DESIGN APRIL 1958 PAGE 56

SURVEY OF FIRING CIRCUITS FOR SILICON CONTROLLED RECTIFIERS OCTOBER 1960 PAGE 60

THERMISTOR COORDINATES
Plotted on this special set of coordinates, thermistor resistance vs. temperature characteristics appear as a straight line. FEBRUARY 1959 PAGE 40

TRANSISTOR AMPLIFIERS FOR DC SIGNALS
Chart summarizes performance of the basic types of direct-coupled and chopper amplifiers.
JUNE 1959 PAGE 48

COLUMNISTS

CHARACTERISTICS OF THE INVENTING PROCESS
Hyman Olken, Staff Columnist.
SEPTEMBER 1959 PAGE 48

CONVENTION NOTES
Ideas for your design file. MARCH 1958 PAGE 63

CREATIVITY IN SELF-ACTUALIZING PEOPLE: PART I
Dr. A. H. Maslow, Staff Columnist.
JANUARY 1959 PAGE 36

CREATIVITY IN SELF-ACTUALIZING PEOPLE: PART II
Discusses the personal qualities, such as "boldness, coverage, freedom, spontaneity, perspicuity, integration, and self-acceptance" that underlie the creative attitude. Dr. A. H. Maslow, Staff Columnist.
AUGUST 1959 PAGE 54

EMOTIONAL BLOCKS TO CREATIVITY
"Must" reading for all. By A. H. Maslow, Staff Columnist. JAN.-FEB. 1958 PAGE 66

ENGINEERING EXECUTIVES — TIME STUDY YOURSELF
A simple time-and-motion study approach for any supervisor who wants to find out where his time actually goes.
OCTOBER 1958 PAGE 22

FAILSAFE MANAGEMENT CONTROLS JULY 1958 PAGE 24

FEASIBLE FANTASY MAY 1958 PAGE 50

GOVERNMENT EROSION OF THE PATENT RIGHT
Disharmony between Constitutional laws and Government Agency Regulations. NOVEMBER 1959 PAGE 46

"HOW CAN THIS BE INVENTION, IT'S OBVIOUS"
After broadly discussing relationships between sicentific ideas, inventions and patents, Rich points out the subtle nature of patentable inventions.
AUG.-SEPT. 1958 PAGE 34

HUMAN ENGINEERING
Measures and fallacies.
Renato Contini, Staff Columnist.
JANUARY 1959 PAGE 32

HUMAN FACTORS IN DESIGN SEPT.-OCT. 1957 PAGE 116

HUMAN FACTORS IN DESIGN NOV.-DEC. 1957 PAGE 80

HUMAN FACTORS IN DESIGN JAN.-FEB. 1958 PAGE 72

"I CLAIM"
Creativity and the identification and protection of its products. Herbert F. Spirer, Staff Columnist.
MAY 1958 PAGE 4

INDUSTRIAL INVENTING
Characteristics of the inventing process.
SEPTEMBER 1959 PAGE 48

INVENTING AND ITS PLACE IN MODERN INDUSTRY
Hyman Olken, Staff Columnist.
FEBRUARY 1959 PAGE 34

MEET ME AT THE FAIR
An engineer's impression of USA contribution to Brussel's Worlds Fair. JULY 1958 PAGE 48

MENTAL PROCESS OF INVENTING
The trial and error combination of mental images. Hyman Olken, Staff Columnist. OCTOBER 1959 PAGE 46

ORGANIZING FOR RESEARCH SEPT.-OCT. 1957 PAGE 104

THE PROGRESSIVE RECIPROCAL REVISION PROCESS
Hyman Olken, Staff Columnist.
DECEMBER 1959 PAGE 42

THE RACE FOR WHAT? JAN.-FEB. 1958 PAGE 80

RESEARCH FOR LONG RANGE PLANNING
APRIL 1958 PAGE 43

SIX SIMPLE STEPS TO UNRELIABILITY
APRIL 1958 PAGE 64

STRATEGY AND TACTICS OF RELIABLE DESIGN
MAY 1958 PAGE 24

TAX CREDITS AND SCIENCE
Martin E. Kagan. JAN.-FEB. 1958 PAGE 4

THE TECHNIQUE OF ORIGINALITY
Hyman Olken, Staff Col. NOVEMBER 1959 PAGE 50

U-DRIVE-IT ENGINEERS: PART I
An appraisal of job-shop employment practices.
NOVEMBER 1958 PAGE 45

U-DRIVE-IT ENGINEERS: PART II
Herbert Spirer, Staff Columnist.
JANUARY 1959 PAGE 34

WESCON: FATTED CALF AT THE COW PALACE
SEPT.-OCT. 1957 PAGE 127

MANAGEMENT

THE ART OF ORIGINALITY
Barriers to originality. SEPTEMBER 1960 PAGE 46

THE ART OF ORIGINALITY
Working principles. OCTOBER 1960 PAGE 58

THE ART OF ORIGINALITY
Working principle II. NOVEMBER 1960 PAGE 52

CASE HISTORIES IN SPRING DESIGN
Consulation with specialists at spring manufacturers is often an easy way out of spring design problems.
JUNE 1958 PAGE 36

DESIGN REVIEWS FOR RELIABILITY
Want to achieve greater ability in systems and components design and cut costs at the same time? Here's an easily administered design review program successfully used by RCA's Missile and Surface Radar Department. JULY 1958 PAGE 28

DO ENGINEERS ENCOURAGE A GOOD COMPANY CLIMATE?
The hen and egg problem. MARCH 1958 PAGE 60

ENGINEER EVALUATION
Correlations vs haloes. SEPT.-OCT. 1958 PAGE 112

THE ENGINEERING SHORTAGE
Statistics vs opinion. SEPT.-OCT. 1958 PAGE 120

EUROPEAN COMMON MARKET
Wanted for export: U.S. products, processes and know-how. APRIL 1958 PAGE 60

FUTURE ENGINEERS by Andrew R. MacAndrew
Production line or custom made?
MARCH 1958 PAGE 5

THE INVENTING PROCESS
Inducing the inventive spark.
JANUARY 1960 PAGE 34

THE INVENTING PROCESS: PART II
Inducing the spark. AUGUST 1960 PAGE 64

MAJOR BARRIER TO CREATIVITY
Panel of experts warns that a management attitude of "creativity-within-limits" too often results in no creativity. FEBRUARY 1960 PAGE 44

PRE-TESTING PRODUCT DESIGNS
Answers to tough questions. MARCH 1958 PAGE 62

REPORT FROM FRANCE by Emile Labin
SEPT.-OCT. 1958 PAGE 118

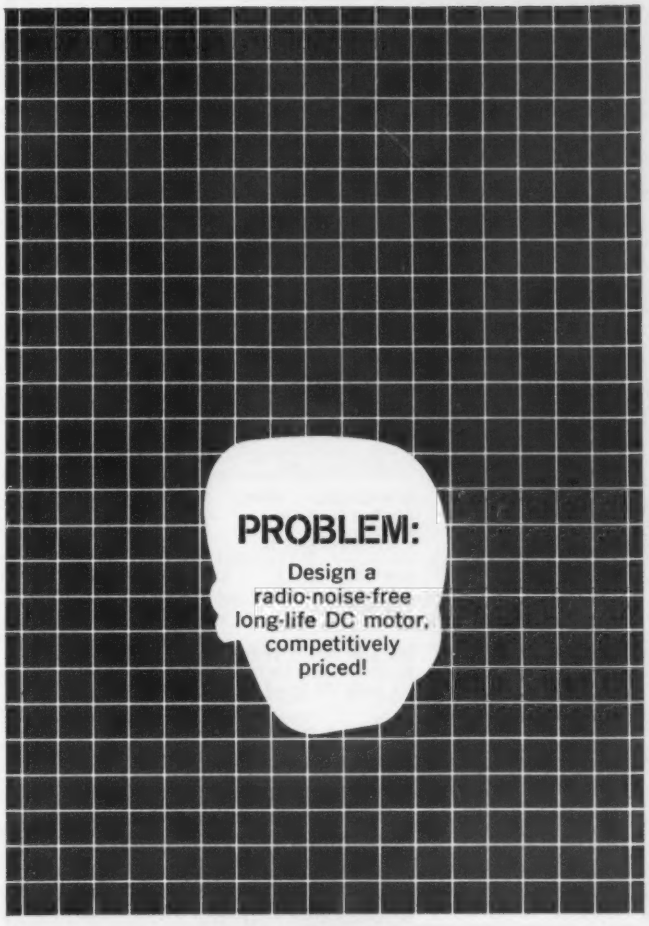
SEMICONDUCTOR DEVICES
An authoritative appraisal of the present and future solid-state industry. JULY 1960 PAGE 37

SEMINARS FOR ENGINEERS
Cutting costs and influencing output.
SEPT.-OCT. 1957 PAGE 108

TRANSITIONS
Training aids in converting the engineer to a supervisor.
SEPT.-OCT. 1957 PAGE 106

VALUE ENGINEERING: Design For Profit
New technique for measuring the true value of everything that goes into a design before production investment. JUNE 1958 PAGE 30

WALL STREET IS WATCHING YOU
Electronic and electromechanical industries in terms of investment potential. JUNE 1960 PAGE 50



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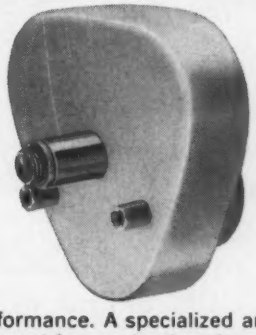

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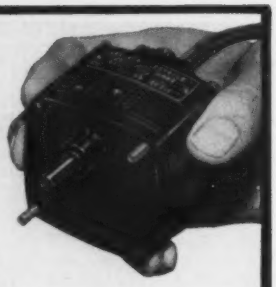

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E.M.D. INDEX

MATERIALS

THE ALPHAS AND BETAS OF IONIZATION JUNE 1958 PAGE 48

CHEMISTRY OF COMPONENTS
Free radicals: energy source for space travel. APRIL 1958 PAGE 54

THE CHEMISTRY OF COMPONENTS
Rare earth possibilities for semiconductors and power sources. NOV.-DEC. 1958 PAGE 46

THE CHEMISTRY OF COMPONENTS
Rare earth storage batteries and ferrites? SEPT.-OCT. 1958 PAGE 34

THE CHEMISTRY OF COMPONENTS
Thermionic emission. JAN.-FEB. 1958 PAGE 23

DUCTILE BISMUTH
New process eases applications. MARCH 1959 PAGE 45

ELECTRICAL SHIELDING TAPE
Aluminum foil laminated to polyester film eliminates cross-talk. JULY 1959 PAGE 31

FERRITES FOR ELECTROMECHANICAL APPLICATIONS
Performance characteristics of ferromagnetic materials developed for gyros, microwave devices and transducers. NOVEMBER 1959 PAGE 22

FILM FORMING DIELECTRIC
Two to six times greater capacitance per unit volume. SEPTEMBER 1960 PAGE 50

HONEYCOMB SANDWICHES
New adhesive film makes strong panels. JAN.-FEB. 1958 PAGE 52

MATERIALS ANALYSIS JAN.-FEB. 1958 PAGE 48

MATERIALS, MISSILES, MICE AND MEN MAY 1958 PAGE 42

MATERIALS PROGRESS REPORT
Research results ready for application in nuclear materials, polymers, resins, lithium compounds. NOV.-DEC. 1958 PAGE 68

MOLY BONDED FILMS
Lubrication for components exposed to high temperatures, corrosion, and extreme loading. APRIL 1960 PAGE 50

NEW EPOXY RESINS
Epoxies demonstrate superior strength and stability at high temperatures. MARCH 1960 PAGE 42

NEW PIEZOELECTRIC COMPOUNDS
Electromechanical coupling coefficient four times that of quartz. AUGUST 1960 PAGE 71

NUCLEAR BATTERIES APRIL 1958 PAGE 22

ONE-PART EPOXY RESIN
Coating intricate shapes for insulating and moisture proofing. JULY 1960 PAGE 34

PROGRESS IN PRINTED CIRCUITRY JULY 1958 PAGE 36

PROGRESS IN PRINTED CIRCUITRY: PART II
By choosing proper electrode conditions and plating potentials you can regenerate cupric chloride baths efficiently permitting automatic process control and infinite reuse of the etchant. OCTOBER 1958 PAGE 27

PROGRESS IN PRINTED CIRCUITRY: PART III
A study of silver migration across and into insulating materials concludes that high d-c potentials and high relative humidity are major contributing factors. NOVEMBER 1958 PAGE 42

RADIATION AND MATERIALS: PART I
Applications of interaction between radiation and matter. David Bandel, Staff Columnist. JANUARY 1959 PAGE 32

RADIATION AND MATERIALS: PART II
Discusses effects of high-level radiation on mechanical and electrical properties of materials. David Bandel, Staff Columnist. APRIL 1959 PAGE 36

SO WHAT ELSE IS NEW?
Chemist report new materials for the electromechanical engineer. David Bandel, Staff Columnist.
JANUARY 1960 PAGE 32

THIN DIELECTRIC SEMI-CONDUCTOR LAYERS
Translation of USSR Technical Report. David Bandel, Staff Columnist. MARCH 1958 PAGE 49

TRACING AND CHASING WITH RADIOISOTOPES
Materials progress report. Ronald C. Vickery, Staff Columnist. MARCH 1958 PAGE 41

VIBRATION ISOLATION
Anti-vibration material simplifies installation and relocation of machines. AUGUST 1960 PAGE 70

WHAT'S IN A CUBIC MICRON?
Just ask the electron probe microbeam analyzer. David Bandel, Staff Columnist. SEPTEMBER 1959 PAGE 42

WIRE INSULATION
Flexible, fluoride film coatings provide exceptionally high insulation value at high temperatures.
JUNE 1959 PAGE 46

NEW TECHNIQUES

ADVANCED TECHNIQUES IN PRINTED CIRCUITRY
Printed circuitry layouts. Automated soldering process. MARCH 1960 PAGE 36
Automated soldering process. MARCH 1960 PAGE 36

AUTOMATIC DRILL
Proximity switches signal slender drill breakage to permit drilling deep holes. NOVEMBER 1958 PAGE 41

AUTOMATC GEAR CHECKER
Automatic inspection for concentricity.
NOV.-DEC. 1958 PAGE 74

AUTOMATIC PRINT READER
Optical technique permits translations at high speed.
OCTOBER 1960 PAGE 56

CHEMICAL & ELECTROCHEMICAL POLISHING
Time-saving techniques applied to removal of burrs from machined metal parts solve some difficult problems.
OCTOBER 1959 PAGE 35

CIRCUIT PACKAGING
New design for printed circuits.
JAN.-FEB. 1958 PAGE 54

DETERMINING THE THERMOPLASTIC PROPERTIES OF METALS
Two simple dynamic tests are an aid in designing springs for high-temperature applications.
MARCH 1960 PAGE 38

DESIGNING FOR MINIATURIZATION
Technique integrates mechanical, electrical and packaging design skills necessary for cramming the most performance into least space. AUGUST 1960 PAGE 44

DYNAMIC TESTING TIMESAVER
Filming a failure with X-ray. MARCH 1958 PAGE 38

ELAPSED TIME COMPUTATION
An inexpensive technique for performing arithmetical operations. JANUARY 1960 PAGE 28

ELECTROFORMING
New latitudes in design. SEPT.-OCT. 1958 PAGE 84

ELECTRON BEAM WELDING AND MACHINING
Precision process packs energy density of 600 million watts per square inch. MARCH 1960 PAGE 40

ELECTROSTRICTIVE CERAMICS
Applied voltage generates radial mechanical displacement. JANUARY 1959 PAGE 29

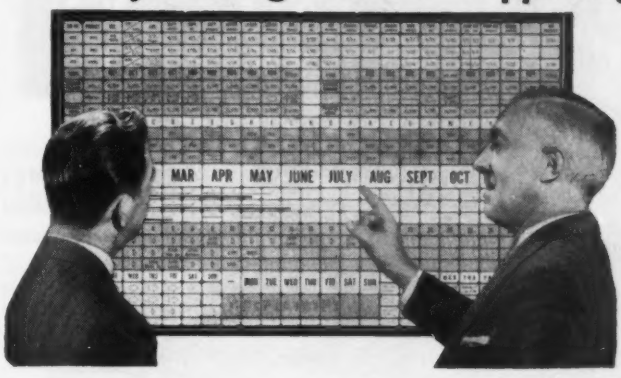
FLASH X-RAY
Shooting explosions with x-ray stills.
NOV.-DEC. 1958 PAGE 72

FLASH X-RAY EQUIPMENT
Freezing high-speed explosions, measuring speed of hypervelocity objects. MAY 1959 PAGE 28

FLEXIBLE AUTOMATION
Low cost numerical control for machine tools.
JANUARY 1959 PAGE 26

GAS BEARINGS FOR HIGH TEMPERATURE
Performance predictions for 1200°F operation.
DECEMBER 1959 PAGE 32

You Get Things Done Better By Seeing What's Happneing



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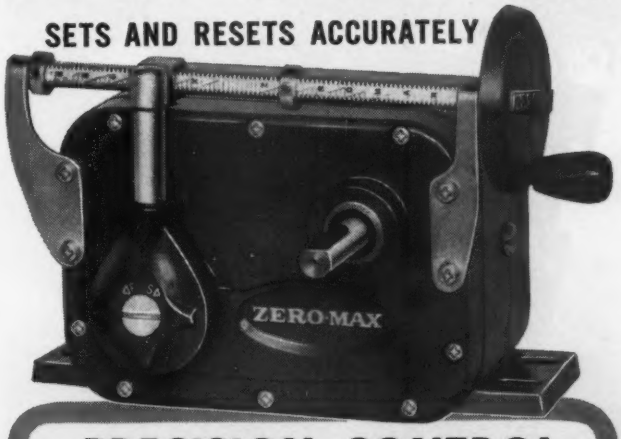

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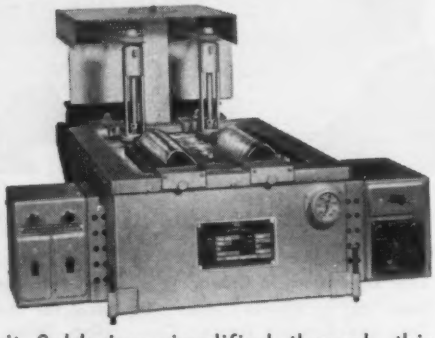

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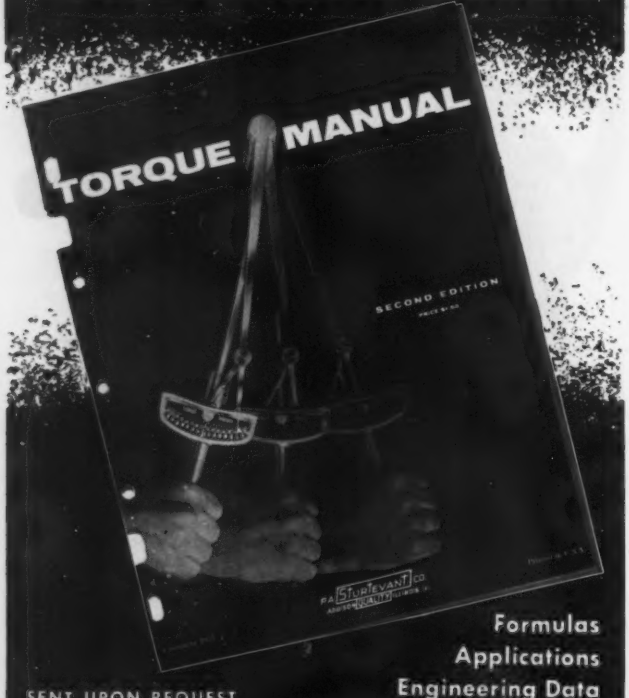

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E.M.D. INDEX

GYRO-ACCELEROMETER PACKAGE
Self-testing capabilities designed into equipment increase reliability. JUNE 1960 PAGE 58

HEAT TRANSFER TESTING
Accurate measurements with simple device. SEPTEMBER 1960 PAGE 52

HERMETIC SEALS
Fully serviceable mechanical seals for hermetic and hi-vacuum packages. OCTOBER 1960 PAGE 52

HIGH TEMPERATURE SOURCE
Small plasma generator produces 2500 to 12,000°F inexpensively. SEPTEMBER 1959 PAGE 37

INDUSTRIAL PRODUCT STYLING
Industrial design eases manufacturing problems and reduces production costs. JUNE 1960 PAGE 64

INFRA-RED INSTRUMENTATION
New detector gives fast response to cool body radiation. New refrigeration technique increases infrared sensitivity. Infrared radiation varies electrical conductivity of gold-germanium. JUNE 1959 PAGE 44

MICROMINIATURE CIRCUITRY
Thin film components for integrated circuits. DECEMBER 1960 PAGE 46

MILLIMICROSECOND PHOTOGRAPHY
Electrostatic image control, focussing and deflection. MAY 1959 PAGE 26

MOBILE VIBRATION TEST LAB
Shakers similar to radio speakers transmit high amplitude vibrations for aircraft structure tests. JULY 1958 PAGE 32

MOISTURE MONITOR
Cell electrolyzes moisture present in stripping gas. SEPTEMBER 1959 PAGE 38

MULTI-PURPOSE MAGNET WIRE
One film wire replaces six or more standard films. JULY 1960 PAGE 26

NEW MACHINE TOOL SYSTEM
Punched tape and transistorized computer convert blueprints into machined parts. APRIL 1958 PAGE 46

NYLON ADHESIVE
Quick-setting high strength bonds with only contact pressure. JULY 1960 PAGE 31

PACKAGE TECHNIQUES FOR SYSTEMS DESIGNS
Beacon transmitter for satellite and space vehicles. Subminiature rate gyro package. One million parts fit into one cubic foot by microminiature technique. Electronic "sardine sandwich" package. APRIL 1959 PAGE 40

PLASMA SPRAY
Coating technique vaporizes tungsten, converts it from gaseous to plasma state and sprays it on cold steel. NOVEMBER 1958 PAGE 40

POT WINDING AND SPACING CONTROL
Microphoto with 60-times magnification shows, extreme parallelism of wires and spacing produced winding equipment. DECEMBER 1958 PAGE 18

POTTING COMPUTER SUB-ASSEMBLIES
Protection against contamination, vibration and shock. SEPTEMBER 1960 PAGE 44

PRECISION BEARINGS
Two methods for measuring bearing preloads. JAN.-FEB. 1958 PAGE 50

PRINTED WIRING DESIGN
New photographic technique for designers. SEPT.-OCT. 1958 PAGE 74

PURE FLUID AMPLIFICATION
Pneumatic devices and systems with no moving parts. JUNE 1960 PAGE 60

RANDOM MOTION TEST TECHNIQUES
Methods for compensating test system resonances. JULY 1959 PAGE 24

RAPID FILM PROCESSOR
From test to film in twenty minutes. JAN.-FEB. 1958 PAGE 46

SCANNING PHOTOMETER
Density vs wavelength curves of spectrum displayed on oscilloscope. SEPTEMBER 1960 PAGE 42

TECHNIQUES IN THE APPLICATION OF SILICON POWER RECTIFIERS
Ratings; forward drop; reverse voltage ratings; thermal properties; protection techniques; overload protection; overvoltage protection; reliability.
FEBRUARY 1960 PAGE 30

ULTRASONIC DRILLING
Applied to ceramic parts. SEPT.-OCT. 1958 PAGE 80

VIBRATION-RESISTANT FASTENER
Locking insert helps reduce aircraft costs by 30%.
JULY 1960 PAGE 30

WIND TUNNEL DESIGN
"Crossed field acceleration". AUGUST 1960 PAGE 54

WIRE PACKAGING
Molded fiberglass harness cuts space, improves performance. AUGUST 1959 PAGE 24

WORKING MODELS
New machine kit for proving designs.
JAN.-FEB. 1958 PAGE 49

X-RAY METHODS
10 basic techniques help solve problems in the application of the x-ray. APRIL 1960 PAGE 48

RESEARCH

ANALOG-DIGITAL DIFFERENTIAL ANALYZER
Digital registers combined with analog elements provide greater precision than conventional analog computers.
NOVEMBER 1960 PAGE 45

CERAMIC FIBERS-TO-METAL
Bond withstands very high temperatures.
SEPTEMBER 1960 PAGE 53

COHERENT LIGHT SOURCE
Optical maser extends radio frequency band into optical range. SEPTEMBER 1960 PAGE 52

COMPREHENSIVE APPROACH TO RESEARCH EVALUATION
Judging past performance for the purpose of guiding future action. MARCH 1958 PAGE 56

DIFFUSED-BASE TRANSISTORS
Epitaxial films reduce switching time.
AUGUST 1960 PAGE 68

GERMANIUM DENDRITES
A "molecular electronics" material.
SEPTEMBER 1959 PAGE 41

GYROMAGNETIC RATIO OF PROTON
New measurement technique improves accuracy by factor of four. JANUARY 1959 PAGE 24

HI-TEMP RECORDER
New developments in recording oscillograph for aviation testing. APRIL 1958 PAGE 51

MAGNETO-THERMIONIC GENERATOR
External magnetic field permits greater design flexibility for high-power generation. NOVEMBER 1960 PAGE 42

MATRIC CALCULUS COMPUTER
One-to-one correspondence between network components and matric entries. SEPTEMBER 1959 PAGE 40

NEW ELECTRON SOURCE
Electron tubes may some day be transistorized.
SEPTEMBER 1959 PAGE 40

NEW THEORY FOR RUSTING OF IRON
Hydrogen ions from water vapor cause destructive reactions. DECEMBER 1960 PAGE 56

PARAMETRIC MODE TRANSISTOR
New development may simplify communication equipment and computers. NOVEMBER 1960 PAGE 47

RESEARCH EQUIPMENT
Superpressure made easy. APRIL 1958 PAGE 50

RUBIDIUM MAGNETOMETER
Here is a new method of indicating the strength of magnetic fields based on light absorption by rubidium vapor.
JULY 1958 PAGE 22

SPACE CABIN DESIGN JAN.-FEB. 1958 PAGE 43

SPECTROSCOPY
VHF radio waves measure behavior of electrons.
APRIL 1958 PAGE 53

SUPERCONDUCTIVITY
Applications now possible in electronic circuits.
SEPT.-OCT. 1958 PAGE 98

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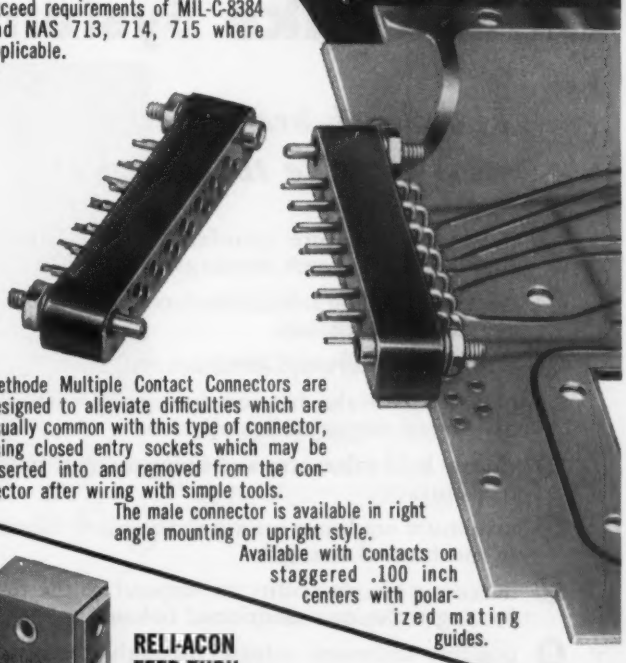

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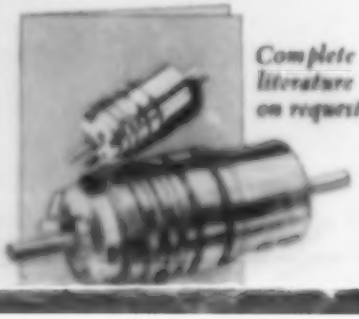

Complete literature on request

ADVERTISERS' INDEX

ADVERTISERS	PAGE
Acromag, Inc.	54
Air Marine Motors, Inc.	10
Amperite Co., Inc.	86
Assembly Products, Inc.	5
Associated Spring Corp.	34
Automatic Electric Co.	27
Automatic Metal Products Corp.	22
Barden Corp., The	25
Barksdale Valves	87
Bodine Electric Co. *Div. of Vocaline*	92
Boehme, H. O., Inc.	71
Boesch Manufacturing Div. *Waltham Precision Instrument Co., Inc.,*	32
Bowmar Instrument Corp.	8
Bristol Motors	91
Burndy Corp.	2
Cannon Electric Co.	51
Carter Motor Co.	30
Clifton Precision Products Co., Inc.	Cover 4
Comar Electric Co.	47
Daystrom, Inc. *Transicoil Div.*	33
Dee Electric Co.	94
Devar Systems *Div. of General Kinetics*	43
Diehl Mfg. Co.	69
Electro Switch Corp.	64
Elgin Micronics *Division Of Elgin National Watch, Co.*	66
Faber-Castell, A. W., Pencil Co.	7
Fafnir Bearing Co., The	50
Fairchild Controls Corp.	24
Gear Specialties, Inc.	88
Globe Industries, Inc,	4
Graphic Systems	93
Gries Reproducer Corp.	97
Hamilton Manufacturing Co.	62
Handy & Harmon	36
Haydon, A. W., Co.	19
Haydon Switch, Inc.	73
Heinze Electric Co.	77
IMC Magnetics Corp. *Eastern Division*	83

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E.M.D. INDEX

GYRO-ACCELEROMETER PACKAGE
Self-testing capabilities designed into equipment increase reliability. JUNE 1960 PAGE 58

HEAT TRANSFER TESTING
A [illegible] ments [illegible] simple device SEPTEMBER 1960 PAGE 52

HERMETIC SEALS
Fully serviceable mechanical seals for hermetic and high vacuum packages. OCTOBER 1960 PAGE 52